PROMOTION OF TRADITIONAL AFRICAN VEGETABLES IN KENYA AND TANZANIA: A CASE STUDY OF AN INTERVENTION REPRESENTING EMERGING IMPERATIVES IN GLOBAL NUTRITION

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by

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PROMOTION OF TRADITIONAL AFRICAN VEGETABLES IN KENYA AND TANZANIA: A CASE STUDY OF AN INTERVENTION REPRESENTING EMERGING IMPERATIVES IN GLOBAL NUTRITION

Anna Whitson Herforth, Ph.D.

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This research was done in the context of an agricultural program promoting production, marketing, and consumption of traditional African vegetables (TAVs) in central Kenya (Kiambu district) and northern Tanzania (Arusha region). The study aims were (1) to evaluate the effect of the program on diet and nutrition of participating smallholder farmer households, and (2) to examine broader questions of how traditional knowledge and crop diversity are related to smallholder farmers' diet quality.

Household surveys of 338 smallholder farmers were carried out at baseline and one year later. Data on agricultural production, marketing, nutrition knowledge, attitudes, medicinal uses of the TAVs, diet, preschool child weight, and household demographics were collected. Focus group discussions contributed information to interpret and expand upon conclusions from the survey.

Program participation was significantly related to TAV consumption in both countries. Other factors predicting increased TAV consumption were acquired knowledge about medicinal value of the TAVs, increased production (in Kiambu), and more favorable attitudes (in Arusha). Reporting of medicinal use of the TAVs, for ailments such as anemia, was common and significantly predictive of TAV consumption, while knowledge about micronutrient content was not. Program participation was not independently associated with diet quality (measured primarily

as dietary diversity and dietary variety), but it was associated with improved economic well-being, which was associated with increased food purchase diversity, which in turn was associated with better diet quality. Crop diversity was significantly associated with dietary diversity in both sites, and was more closely related to home food consumption than to purchased food consumption. Farmers used many varieties of the same crop for different purposes, and within-crop diversity was correlated with increased consumption of that crop.

The program appeared to affect TAV consumption and factors related to overall diet. Agricultural programs may need to increase attention to crop diversity to reach the goal of improved food security for smallholder farmers in the sub-Saharan African context. Within-crop diversity may also have important consumption and nutritional effects. Nutrition behavior change efforts may be most successful if they build on pre-existing knowledge and practices, which may be more important consumption motivators than introduced knowledge.

BIOGRAPHICAL SKETCH

Anna Whitson Herforth grew up in Horseheads, New York. She attended Cornell University for undergraduate studies, where she did several research projects on agriculture and ethnobotany in Latin America: first in Mexico, then in Dominican Republic and finally in Peru, where she completed a senior honors thesis, *Anti-fungal Plants of the Peruvian Amazon: a Survey of Ethnomedical Uses and Bioactivity*. In 2002 she received a B.S. in Plant Science, *summa cum laude*.

Inspired to study health and nutrition after observing the many ways people use plants for health as food and medicine, she was awarded a National Science Foundation Graduate Research Fellowship to study the links between traditional foods, health and nutrition in the context of changing environments. She attended Tufts Friedman School of Nutrition Science and Policy where she completed a M.S. in Food Policy and Applied Nutrition, with a specialization in nutrition interventions. During her master's degree, she worked as an intern on a food security program in Bangladesh with Save the Children. She then went to India in 2005 to work with the Micronutrient Initiative on drafting a National Micronutrient Investment Plan.

Anna returned to Cornell in 2006 to study International Nutrition. Being drawn to Cornell because of the expertise present in both international agriculture and international nutrition, she worked with several professors and other interested graduate students to create the Food, Agriculture, and Nutrition Group, to link agriculture and nutrition research and practice on campus. Between research trips to Kenya and Tanzania, she also consulted with UNICEF in Ethiopia.

She currently works at the World Bank as a Nutrition Specialist on multisectoral issues of nutrition, agriculture, and the environment.

This document is dedicated to all the farmers who dedicated their time and enthusiasm to this research.

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I owe a huge debt of gratitude to those who worked closely with me in Kenya and Tanzania to carry out this research. It is difficult to express how smoothly and quickly the research went, and just how much of that effortlessness was due to the fact that I was carried by incredibly kind and capable partners at CIP, AVRDC, and Farm Concern. First and foremost, Jan Low made this research possible. Her openness to my involvement after I literally showed up on her doorstep at CIP was the lynchpin of success for this project. Wachira Kaguongo, who worked together with me every day I was at CIP, cannot be bested for his dedication, collegiality, carefulness, and management - all of which were crucial to the success of the survey. Nancy Karanja and Mary Njenga taught me by example how community work should be done. Emily Ndoho and Naomi Zani were instrumental for an efficient work flow at CIP. I am deeply grateful to Stephan Pletziger at AVRDC-RCA for going to bat for me when I arrived in Tanzania, magically finding outstanding enumerators, and for being my one constant, vital source of contact with the program between survey years. Detlef Virchow, Abdou Tenkouano, and Jackie Hughes generously extended a welcome to work and reside at AVRDC-RCA, where I benefited greatly from assistance from Hassan Mdiga, Mel Oluoch, and Mama Guga, and enjoyed the camaraderie of Shilpi Saxena, Jerry Miner, Remi Kahane, Severin and Marcella Polreich, Jan Helsen, Christine Ludwig, Annette and Fortunata. Everyone at Farm Concern - Mumbi Kimathi, Grace Ruto, Janet Magoiya, Mate Murithi, Hellen, Stanley Mwangi, Furaha, and Irene Mathenge - embodies the spirit of Good Works in their activities, and I cannot thank them enough for how kind, helpful, and informative they were to me. They were truly essential to my involvement in this work, and I am honored to call them friends and colleagues. The credit really goes to Grace for first giving me the idea to reconsider my pre-planned project and to instead join the TF Project, which is a move I am utterly thankful for. I remain awestruck by the number of talented people who welcomed me into this project with kindness and helped me at every turn.

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They say that behind every successful man is a woman. On the flip side, if

I might call myself a successful woman for finishing this work, it is because a wise, dedicated man has been behind me at every single step. There is no way to adequately express my thanks to my husband, Daniel Young-joon Kim, for the steady support he has offered to help me complete this degree. Having gone through the process of getting a Ph.D. once already [139], Daniel willingly went quite intimately through the experience again with me, which is more than anyone should have to do. I thank him for his unwavering belief in the value of what I was doing, uncomplaining support while I traveled for eight months to collect data, for supplying the latest and greatest technology to ensure that my work was as efficient and painless as possible, crafting ingenious solutions to drafting and formatting issues, discussing data integrity and logic, staying up late in solidarity while I worked, beautifying my work space with roses, and for doing it all with tremendous love. I cannot imagine what the last years would have been like without him, nor can I imagine the future without him - and I joyfully look forward to many years together as a family.

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INTRODUCTION: EMERGING IMPERATIVES FOR GLOBAL NUTRITION IN THE SUB-SAHARAN AFRICAN CONTEXT

Large sections of this chapter are taken from: Herforth, A. Nutrition and the Environment: Fundamental to Food Security in Africa. In: Pinstrup-Andersen, P (Editor). *The African Food System and its Interaction with Human Health and Nutrition.* Ithaca, NY: Cornell University Press, 2010 [103].

1.1 Nutrition and food systems in sub-Saharan Africa

In sub-Saharan Africa, nearly all nutrition interventions operate in the context of agriculture. Agricultural interventions should be considered as a primary means to affect nutrition - not just because agriculture produces food, but also because agriculture is the primary livelihood of most Africans. Food production, income, knowledge and behaviors interact within household contexts to affect nutritional status for all household members. The complexity of production and consumption decisions at the household level, and the factors that influence them, affect agriculture and nutrition interventions. Better understanding of how farmers use available resources to ensure nutrition and health inform much-needed strategies and advice to reduce food insecurity and malnutrition, and to create policies that will ensure a health-promoting food system.

1.1.1 Farming is the main livelihood in sub-Saharan Africa

As the major source of food for the planet, agriculture - what is produced, where, and how - affects nutrition for all people. The linkages between agriculture and nutrition are especially direct in sub-Saharan Africa, where more than two-thirds of the population depends on agriculture for their livelihood; among rural populations, about 90% are agricultural [298, 53]. The vast majority of these are smallholder farmers, who are typically net buyers of food, relying on their agricultural production for income as well as for directly consumed food. Problems of food insecurity and malnutrition run deep in this rural and agricultural population, so improving the nutrition situation requires insight into agriculture at the smallholder farmer level.

1.1.2 Food insecurity

According to the United Nations, "Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for a healthy and active life" [70]. No indicator is consistently used across sub-Saharan Africa to measure the prevalence of food security according to that (or any) definition, but approximations show that food insecurity is widespread. The Food and Agriculture Organization of the United Nations (FAO) estimates that one-third of people in sub-Saharan Africa are food insecure or "undernourished," based on an indicator of caloric availability [73].[1] Others have estimated significantly higher levels of food insecurity in sub-Saharan Africa using household expenditure surveys [241]. Poverty is closely related to food insecurity, and more than 46 percent of the population in sub-Saharan Africa lives on less than $1 per day [272]; the rate is higher in rural areas than in urban [299]. With business as usual, the proportion of food-insecure people in sub-Saharan Africa will stay constant at one-third of the population, and the number of food insecure will rise to 265 million by 2015 [201].

[1] According to the FAO, "Undernourishment refers to the condition of people whose dietary energy consumption is continuously below a minimum dietary energy requirement for maintaining a healthy life and carrying out a light physical activity" [75].

1.1.3 Undernutrition

Poverty and food insecurity manifest themselves as malnutrition, and in a vicious circle, malnutrition causes poverty through loss of productive capacity. The number of undernourished children in sub-Saharan Africa has increased over the past decade; the percentages of stunted and underweight children have stayed constant at about 35 percent and 24 percent, respectively, since 1995 [264]. These high rates of child malnutrition contribute greatly to making mortality rates for infants and children under five years of age in sub-Saharan Africa the highest in the world [269]. Malnutrition accounts for 35-56 percent of all child deaths, mostly because malnourished children are much more likely to die from disease than well-nourished children [190, 19].

More common than death from malnutrition is disability: malnutrition limits work productivity. In sub-Saharan Africa, this means reduced agricultural productivity, which compounds the problem of food insecurity. Malnutrition in childhood can reduce learning potential, as well as adult work capacity, earning capacity, and productivity [161, 92, 281]. Both protein-energy malnutrition and micronutrient malnutrition (often called "hidden hunger") contribute to lost productivity. Deficiencies in iodine and iron in infancy and young childhood can result in irreversibly impaired mental development.

Even mild iodine deficiency reduces IQ by 10-15 points on average, limiting productive capacity [158]; 43 percent of the African population is iodine deficient [264]. Iron-deficiency anemia not only impairs mental development and physical growth in children [157, 233], who consequently have a lower potential for productivity in adulthood, but also reduces work capacity in adults [93]. National rates of iron-deficiency anemia among children under age five in sub-Saharan African countries range from a low of 37 percent (South Africa) to a high of 86 percent

(Sierra Leone) [171]. Vitamin A deficiency causes reduced immune function and blindness; 32 percent of children under five in sub-Saharan Africa are vitamin A deficient [264].

Macro- and micronutrient malnutrition also worsens the progression of HIV/AIDS. This interaction is important to consider in sub-Saharan Africa, where about 5 percent of adults live with the disease; in some countries, rates are much higher [265]. Those with HIV/AIDS die faster if they are generally malnourished [76] or micronutrient malnourished [12, 232]. Better nutrition is needed to support immune function, and HIV/AIDS increases energy requirements [291]. Also, given that antiretroviral treatments must be taken on a full stomach, limited food compromises treatment for the disease.

Because of its high toll on human health, resources, and well-being, malnutrition reduces national and regional economic growth substantially. In most countries in sub-Saharan Africa, malnutrition reduces gross domestic product (GDP) by 1-2 percent [171]. Losses come from reduced physical and mental capacity, as well as reduced school attendance and increased health care costs [297]. Undernutrition also reduces agricultural productivity, especially when compounded with disease [94, 59]. Further losses are incurred from the growing double burden of malnutrition-including overweight and related diseases-which is rising even in some rural areas of sub-Saharan Africa [293, 168], where non-communicable diseases carry high rates of disabling complications [14, 276].

1.1.4 Nutrition transition and obesity

Not only are child undernutrition rates stagnating, but adult obesity and chronic disease incidence are quickly increasing in some areas. In developing countries around the world, consumers are shifting from traditional diets to eating patterns high in refined starches, oils, and added sugars [58, 195]. This shift has led to a "nutrition transition," marked by increases in overweight, obesity, and related chronic diseases such as diabetes and heart disease [204]. Although undernutrition remains the major problem, adult overweight exceeds underweight among urban women in nearly all sub-Saharan African countries. In a few countries, the same is true for rural women [168]. Among urban women in sub-Saharan Africa, almost one-third are overweight or obese [168]. Prevalence of obesity in children, though still only 5 percent on average, is rising sharply in Africa, more rapidly than anywhere else in the world [297, 264]. Diabetes prevalence in sub-Saharan Africa is expected to more than double from the 2000 rate by 2025 [110].

While many of the poor in sub-Saharan Africa suffer from insufficient calories, poor and rich alike may have limited access to micronutrient- and phytonutrient-rich components of a diverse diet. Dietary diversity is crucial for genuine food security, which encompasses nutritional quality and food preferences. Because of its empirical association with caloric and nutrient adequacy and, in turn, positive child growth and nutritional status [222], dietary diversity has itself been proposed as a measure of household food security [106, 72]. Dietary diversity is generally quite low in sub-Saharan Africa. In a study using household-level data from 12 countries in sub-Saharan Africa, 8-63 percent of households were found to consume diets low in diversity-that is, they consumed fewer than four out of seven food groups [241].[2]

Dietary diversity usually increases with income; the ability to purchase food also helps avert seasonal variation in food availability on farms [259]. Accordingly, the straightforward policy solution to food insecurity would be to improve incomes through some combination of national economic growth, targeted income

[2] The seven food groups were (1) cereals, roots, and tubers; (2) pulses and legumes; (3) dairy products; (4) meats, fish and seafood, and eggs; (5) oils and fats; (6) fruits; and (7) vegetables.

generation for the poor, and possibly reduced prices for essential goods, including staple grains. Many staple and export crop-oriented agricultural programs aim to increase farmers' household income under the assumption that the household could then more easily purchase foods to make up a diverse diet. Income growth is important but not sufficient, however, to rid sub-Saharan Africa of food insecurity.

Most immediately, income increases will not achieve food security for Africa because in many parts of Africa, the components of a diverse diet are simply not available. Figure 1.1 shows that per capita availability[3] of nonstarch commodities is too low to meet every person's needs. Pulses are the protein source (complementary with grains) most accessible to the majority of poor households in sub-Saharan Africa; consumption of pulses is also associated with lower incidence of chronic disease, presumably because of their inverse association with meat consumption [115, 280, 79]. Only 26 grams of pulses are available per capita per day, however, providing only about 10-15 percent of the daily adult protein requirement.[4] Slightly more than 200 grams of fruits and vegetables are available, about half the World Health Organization minimum requirement of 400 grams [294]. Inadequate supply pushes up the prices of these dietary components and contributes to continued poor nutrition.

Diet patterns typical of the nutrition transition show that although overall dietary diversity tends to increase with increasing incomes, the quantities consumed of vegetables and vegetable proteins (mainly pulses) decrease and animal fat and protein consumption increases steeply [58]. Poor availability and accessibility of

[3]Food quantities available for human consumption include production and imports minus exports, livestock feed, seed, additions to stocks, and losses.[75]

[4]The protein requirement for adults is 0.8 grams per kilogram body weight per day [113]. Cereals also contribute to protein intake (the amount varying by crop), forming a complete protein in combination with pulses. Accounting for per capita milk availability of 81 grams [75] contributes another 6 percent to the daily adult protein requirement. Per capita meat, egg, and fish consumption (54 grams per capita per day) would contribute another 14 percent toward protein needs if equally distributed, but consumption of these foods is highly skewed toward the wealthy.

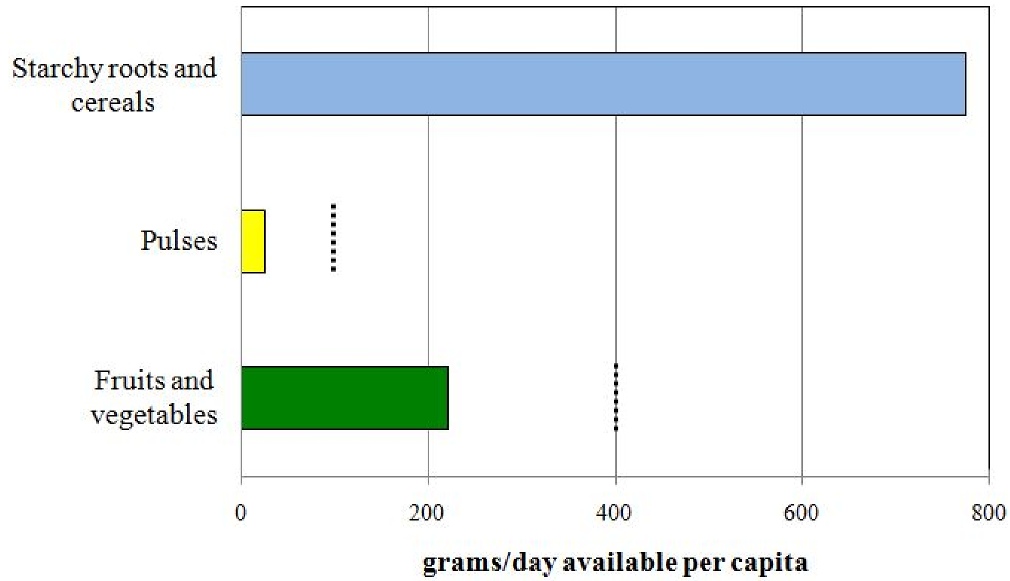


Figure 1.1: Per capita availability of nonstarch food commodities
Note: Dotted lines represent approximate quantities that would fulfill dietary needs for pulses, and fruits and vegetables, under a scenario of perfect distribution. These quantities are based on WHO/FAO guidelines for fruits and vegetables, and on the adult protein requirement for pulses (accounting for protein content of cereals, and assuming low intake of animal-source foods). Data source: FAOSTAT [75]

good-quality fresh fruits and vegetables is a problem for people at risk of obesity as well as those affected by undernutrition. There are strong economic reasons for high-calorie and "empty-calorie" food choices where sugars, starches, oils, and high-fat animal products are far cheaper sources of calories than fruits and vegetables [57]. Diversification of food production to include more vegetables, fruits, and legumes can help to avoid the situation now seen in countries that have experienced this nutrition transition, where obesity has become the major nutrition problem.

1.2 Food availability and access in sub-Saharan Africa

Compounding the insufficient availability of nonstaples is lack of access to markets. sub-Saharan Africa has the highest proportion of people with poor access to markets in the world. Only 20 percent of the rural population is able to reach a viable market in less than two hours, and nearly 35 percent must travel five hours or more [299]. Inadequate and poorly maintained roads and lack of cold chains make it difficult to transport food, particularly perishable food, from areas of higher to lower availability. This lack of infrastructure, the inadequate availability of markets, and the time and cost involved in reaching them together create a barrier to obtaining diverse diets, with the result that home production or wild collection may be among the few ways to get access to a diverse diet.

Another dimension of lack of access to food involves how income is used within a household. Assumptions about perfect intrahousehold allocation of resources that achieves maximum food security for all household members generally are not born out. Several factors affect how income is spent, including the form of the income, whether it comes regularly or in sporadic large payments, and who controls it [199]. Women's control of income in particular tends to have a more positive effect on household and child nutrition than men's control of the same income [242, 183]. Often, the crops controlled by women are horticultural.

Improved national and household income needs to be combined with crop diversification in sub-Saharan Africa to ensure food security. There is strong evidence that households with home gardens consume more fruits and vegetables than those without home gardens [28, 30, 68, 69, 105, 165, 254]. Of course, these households continue to consume staple crops as well, so it is likely that the added produce increases dietary diversity. In Kenya and Tanzania, a study of smallholder, semi-subsistence farmers found that the number of crops cultivated was strongly associated with dietary diversity (see Chapter 6). This is not to say that smallholder production should be subsistence oriented. On the contrary, nonstaple crops offer significant opportunities for value addition, and farmers may be most likely to diversify production if they can market their produce for good returns. Crop diversification can affect dietary diversity by increasing income security (reducing farmers' risk in depending on only one or a few key crops) and by increasing harvests of minor crops, which women typically sell (see Figure 1.2). These nonstaple crops are often most suitable for value addition, such as bundling, drying, and specialized marketing.

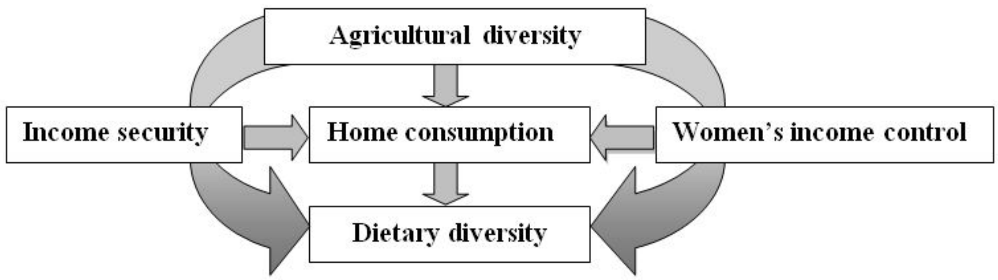


Figure 1.2: Hypothesized links between agricultural and dietary diversity

1.3 The links between nutrition, agriculture, and the environment

Agricultural diversity in sub-Saharan Africa is important to providing dietary diversity. Increased agrobiodiversity also may be essential for providing the ecosystem services needed for food production and nutrition. Ecosystem services are "the various ways that organisms, and the sum total of their interactions with each other and with the environments in which they live, function to keep all life on this planet, including human life, alive" [31]. The Millennium Ecosystem Assessment [39] delineates four types of ecosystem services: (1) supporting services, such as nutrient cycling and soil formation; (2) provisioning services, such as food, fresh water, wood, and fuel; (3) regulating services, such as water purification and climate and disease regulation; and (4) cultural services, providing opportunities for aesthetic, recreational, and spiritual needs. The services ecosystems provide make food production possible, as well as affecting human health and disease through provision of fresh water and air. Soil and water are the building blocks of food, with essential support from microbes and animals. Food security dwindles without healthy soil, adequate water, and an ecosystem that supports microbes, natural soil fertilizers and aerators, insect pollinators, and pest controllers.

The environment is the foundation for food security and nutrition. Ecosystem services are the basis for food production and the caloric and nutrient yields necessary for human nutrition. Adequate nutrition is necessary for humans' ability to work and to seek food. How people seek and produce food, from crop choices to agricultural use of fossil fuels and water, affects the environment, which in turn affects nutrition by dictating which crops can be grown where and when and what they will yield (Figure 1.3).

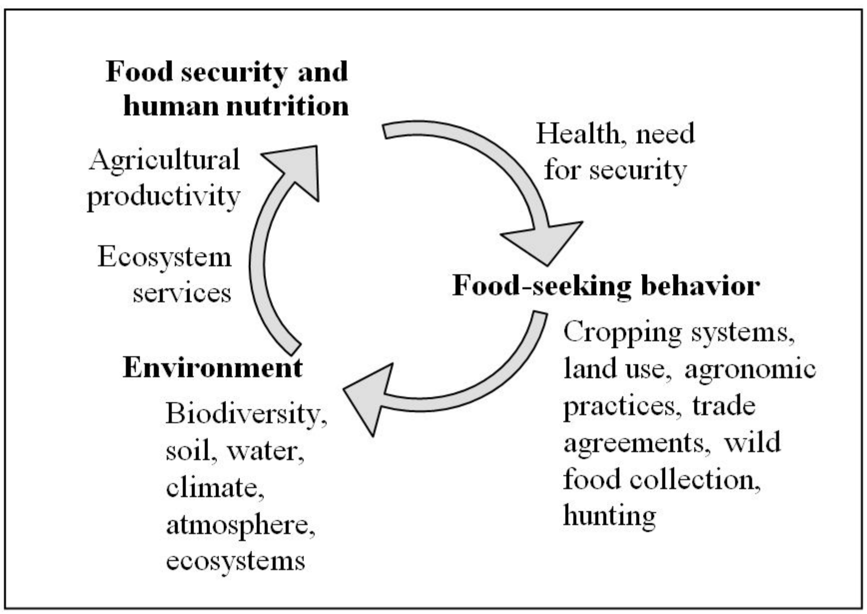


Figure 1.3: Flow between nutrition, food-seeking, and environment

Components of "the environment" include biodiversity, soil, water, climate, and ecosystems, all of which provide ecosystem services. Table 1.1 shows examples of how each affects food security and human nutrition and is affected by food-seeking behavior.

Table 1.1: Components of the environment, how they affect human nutrition, and how they are affected by human food-seeking behavior

Component	**How it affects nutrition**	**How it is affected by food-seeking behavior**
Biodiversity • Wild biodiversity • Agrobiodiversity – crop species and varieties – non-cultigens – insects – microbes	• Affects the diversity of foods and medicines available for human consumption • Affects yields (directly and through disease resistance) • Affects development of varieties that are particularly high yielding, nutrient-rich, or adapted to specific environments	• Competition for space between wilderness and farming affects ecosystems, habitats, and number of species • Cultivation or gathering based on desired characteristics affects genetic diversity in crops and wild species • Cropping systems, trade agreements, marketing and transportation, and cultural and consumer preferences affect number of species and varieties grown • Agronomic practices affect insect diversity, including pollinators, pests, and predators
Soil • Nutrient content • Structure • Biodiversity (microbes, microfauna)	• Affects yields • Affects nutrient content of crops	• Species grown, continuous cultivation, and other agronomic practices (tilling, mulching, fertilizing, etc.) affect fertility (nutrient content and structure) and soil biodiversity
Water • Irrigation water • Drinking water	• Affects yields • Affects cleanliness and safety of food and drink • Affects exposure to waterborne and insect vector-transmitted disease	• Water resource management affects water quantity and quality • Agrochemicals and soil erosion affect water quality • Irrigation can increase yields but over-irrigation can cause salinization • Choice of drought-resistant crops and varieties can conserve water

Table 1.1 (continued)

Climate • Temperatures • Weather and storms	• Affects yields • Affects what crops can be grown where and when • Affects wild food availability • Affects exposure to infectious disease (such as malaria)	• Fuel use in food production and transportation releases greenhouse gases • Livestock activities produce 1/5 of all greenhouse gases [249] • Forest destruction for crop production reduces carbon sink; alley cropping and forest regeneration increase it • Soil erosion and related cropping practices affect soil carbon sink
Ecosystems • Capacity to provide foods • Reversibility/ irreversibility of land use shifts	• Affects land fertility • Affects wild food availability (such as ocean fish, Brazil nuts)	• Land use changes affect ecosystem size; rainforest destruction and desertification are largely irreversible changes • Food system-resultant climate change endangers certain ecosystems

1.3.1 Weakened ecosystem services underlie food insecurity

Fragile ecosystems and environmental degradation - of soil, water, climate, and biodiversity - endanger nutrition. Degradation of soils that were old and weathered to start, makes food production more difficult. Water scarcity and injudicious water use has effects on both food production and disease risk, which may become more exaggerated with climate change. Loss of biodiversity may be related to undernutrition, by loss of yield potential, crop disease protection, or reduced possibilities for nutrient adequacy in diets, and overnutrition, by loss of phytochemial-dense traditional diets that could counteract shifts toward obesogenic diets.

Low per capita agricultural productivity is a persistent challenge to livelihoods in sub-Saharan Africa. Yields and yield advances are significantly lower for sub-Saharan Africa than for other regions of the world [300]. Population in the region is growing at a rate of 2.2 percent per year [274], whereas agricultural productivity has risen at a rate of only 1.3 percent per year since 1980 [36]. Although average yields are still rising, there is wide variation between fields, with the poorest farmers often seeing the least improvement, if not declines. This situation is related to governments' perennially low investment in agriculture, but the weakening of ecosystem services also plays an important role.

A larger population means that each successive generation has less land to till on average. There has been a rapid decrease in mean farm size; for example, from 1960 to 2000, average landholdings in Kenya and Ethiopia shrank 50 percent [114]. Average landholdings in other sub-Saharan African countries declined 25-45 percent in the same time period (see Figure 1.4). The increased pressure on land has changed farming practices, often resulting in lower productivity. Farmers are more likely to continuously crop their land for decades [153], unable to let it lie fallow because of the ever-pressing need for food and income. Low crop diversity worsens the situation because continued dependence on one or two crops mines the same nutrients from the soil year after year. The process can be very rapid: a research group in Kenya found that both soil nitrogen and soil organic carbon declined 37-73 percent in the first four years of cultivation [245].

Nutrient mining in sub-Saharan Africa, exacerbated by continuous cropping and low crop and livestock diversity, causes declines in crop productivity [224]. Experimental data from the highlands of Kenya [181] illustrate yield declines in relation to number of years of continuous cropping: there, soils lost more than half of their productivity after 35 years of continuous cultivation. When asked

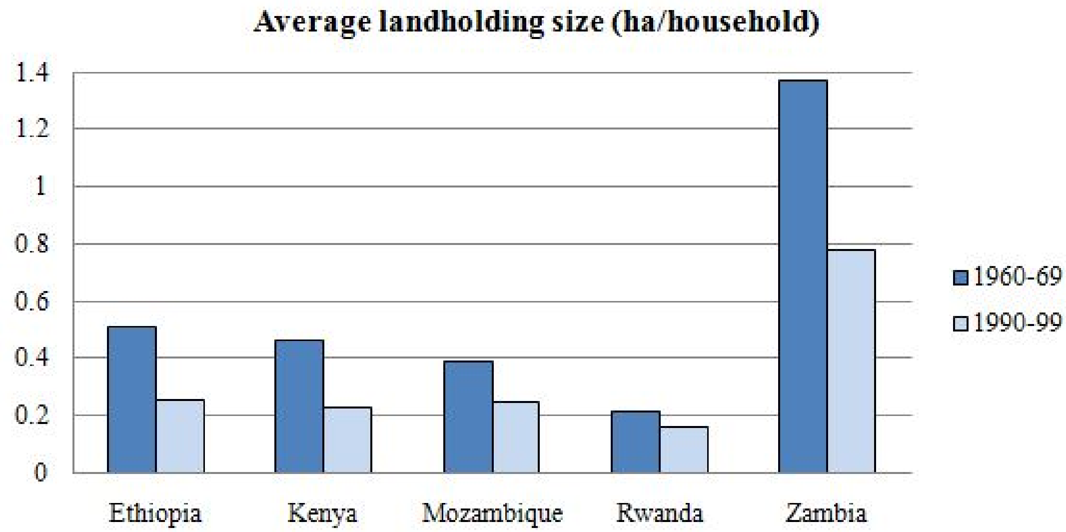


Figure 1.4: Average household landholding, 1960s vs 1990s.

why they would need to take action to improve productivity, farmers in a similar situation in Zambia commonly responded, “The soils are tired” [82]. Furthermore, soil nutrients are important not only for yields, but also for the mineral content of foods. The occurrence of zinc, iodine, and selenium deficiencies in humans is geographically correlated with respective soil deficiencies [87, 98].

Soil erosion contributes to productivity losses through loss of nutrients as well as the physical base for cultivation. Severe dry and rainy seasons in much of Africa make bare, exposed soil extremely vulnerable to wind and water erosion. Although the exact estimates are debatable, erosion may be reducing productivity across sub-Saharan Africa by 0.5 percent a year [146].

The result is that steady soil depletion, shown as yearly negative nutrient balances, is occurring in all sub-Saharan African countries [101] (see Figure 1.5).

Most African soils are ancient and weathered to begin with; erosion, leaching, increasingly intensive cultivation, and practices such as low use of fertilizer and few organic amendments degrade them further. The rate of nutrient loss in sub-Saharan Africa is five times higher than the average rate of replacement by

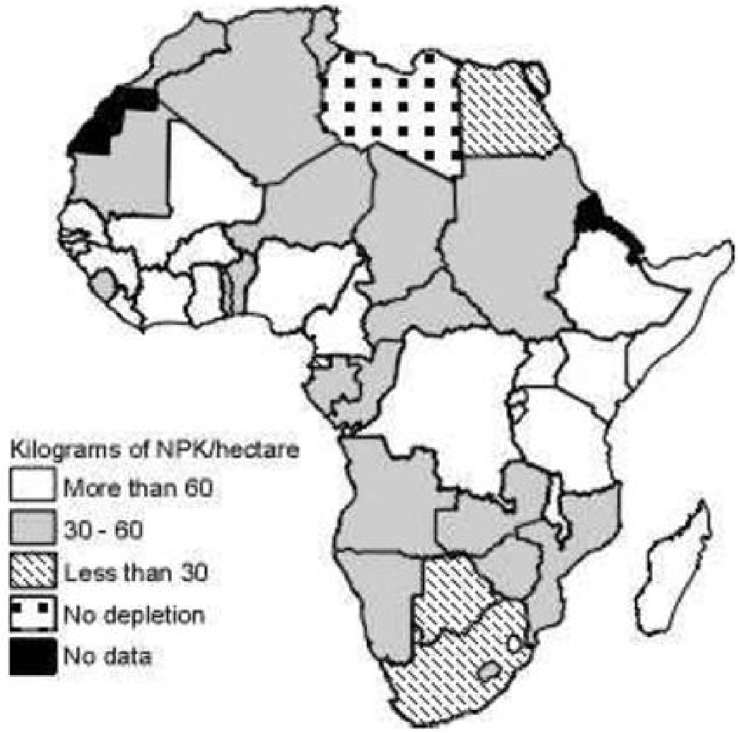


Figure 1.5: Soil depletion by country: soil nitrogen, phosphorus, and potassium lost per year, 1993-1995 [101]. Reproduced with permission from the International Food Policy Research Institute (www.ifpri.org)

fertilizers [298]. Valuing nutrients at the price of fertilizer, nutrient depletion is estimated to cost 7 percent of agricultural GDP in the region [56].

Soil lost from fields often ends up as siltation in watersheds, reducing water quality [227], which is particularly problematic for sub-Saharan Africa, where lack of adequate water is a major constraint to crop and animal yields as well as human health. Most African farms rely on rainfall, with only 4 percent of agricultural land irrigated [90]. Although low water use limits annual yield potential, expansion of irrigation may be limited since the available water supply for many parts of sub-Saharan Africa is projected to decrease by up to 10 percent by the end of the century because of climate change [46]. Moreover, irrigation must be taken up with care, because overirrigation can cause waterlogging and salinization, reducing arable land. It is extremely difficult to restore saline soils. Salinity affects nearly

3 percent of arable land in Africa as a whole and much more in certain regions, such as in Kenya where nearly 15 percent of arable land is saline [273, 162].

In all, 5 to 10 million hectares are lost annually to severe degradation, including desertification, with the result that 1.4-2.8 percent of total cropland, pasture, and forest may be lost between 2000 and 2020 [228]. In sub-Saharan Africa, it is estimated that 60 million people will be forced to migrate from desertified areas by 2020 [266]. This migration would increase pressure on arable land and cities, further straining the ecosystem services that are the foundation for food security and nutrition. See Figure 1.6 for a visual representation summarizing the causes of low agricultural productivity in sub-Saharan Africa.

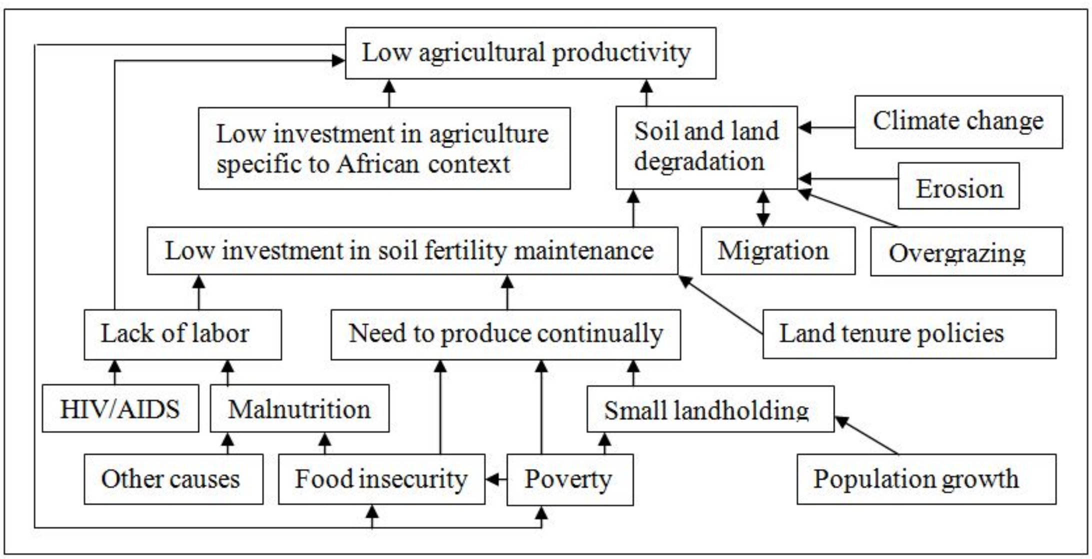


Figure 1.6: Causes of low agricultural productivity in sub-Saharan Africa

1.3.2 Environmental degradation and malnutrition

Environmental degradation is associated with food insecurity and undernutrition. In West Africa, child under-five mortality is highest in areas of high soil degradation [267]. Ecosystem type is associated with infant mortality rate: drylands, which provide the most limited ecosystem services in terms of soil fertility and water availability, have the highest rates of infant mortality [39]. Maps of rainfall and poverty in Kenya reveal that those living in the driest areas tend to have higher poverty rates and poorer-quality housing than those in areas that receive more rainfall [301] – accepting poorer-quality housing rather than less food when resources are limited is a typical coping strategy. Another study in central Kenya corroborates these trends: farms with "low" and "medium" soil natural resources were found to yield roughly half the farm income of farms with "high" soil natural resources [235]. Although these relationships lack a clear causal direction or pathway, even where poverty and food insecurity push people to live on poor-quality land, lack of ecosystem services is likely to exacerbate their vulnerability.

There are many histories of indigenous groups for whom environmental degradation, resulting in acculturation to mainstream culture and foods, results in food insecurity and poor health [102, 120, 123]. Johns and Sthapit (2004) note that "changes in land use, including disturbance, deforestation, and appropriation of natural areas, diminish opportunities for gathering and hunting the essential wild components of many traditional food systems" [123]. Wild foods, and supporting the environment needed to obtain them, often make significant contributions to dietary quality [215, 145, 184, 124, 27]. Both biological and cultural diversity, which are often correlated [250], are linked to diverse, plant-source food diets. Several studies have linked nutrition transitions to decline in traditional diets [211, 123, 118, 160].

The nutrition transition and dietary homogenization contributes to the food insecurity and malnutrition of the have-nots. The current food system in sub-Saharan Africa aggravates both problems at opposite ends of the BMI spectrum, and they are linked partly through the environment. Changing food preferences in

Africa, especially in urban areas, are implicated in water and land scarcity. The demand for animal source foods is increasing more rapidly than the demand for grain in Africa [71] – a situation that will greatly increase water requirements. Beef production, for example, in many environments requires 15-35 times more water than wheat or sorghum cultivation [34]. In addition, increased livestock grazing is likely to result in further land degradation. Most of the human-induced soil degradation in Africa has resulted from overgrazing [202].

1.4 Established pathways from agriculture to nutrition

Alleviating both undernutrition and overnutrition in sub-Saharan Africa is closely tied to food systems, and solutions cannot come from the health sector alone. Agricultural interventions are called for to address public health problems. As such, it is useful to understand the main pathways by which agriculture can affect nutrition.

A major review of research on agriculture-nutrition links by the World Bank in 2007 summarized five main pathways through which agriculture affects nutrition: **home consumption, income generation, women's empowerment, lower food prices, and national macroeconomic growth** [298]. There has been a progression in understanding these paths in the last few decades.

In the Malthusian thinking of the 1970s, an increase in food production and a concomitant **decrease in food prices** would be enough to meet the nutritional demands of a growing population. When widespread malnutrition persisted despite huge gains in food production from the Green Revolution, which reduced food prices at national and regional levels, the conclusion that higher production was necessary but not sufficient for reducing malnutrition led to a shift in focus toward increasing income in the 1980s [197, 298]. Increased production alone did not improve nutrition for several reasons. One, the *local* food supply does not necessarily increase if the increased food being produced is exported. Two, if a farmer increases production of the same commodity as many other farmers, the price per unit of the commodity may drop so that gains in income are not commensurate with increased production. Three, if farmers cannot access markets to sell their crops, the excess produce they have may well rot in the field and fail to benefit the farmer in any way. An increase in production must be accompanied by market access [198].

Even given functional markets, **increased income** is not sufficient to ensure good nutrition. If farmers engaged in cash cropping displace their food crops with cash crops, food purchases do not necessarily compensate for the reduced food available from home production [198]. When production is oriented toward income, specific target crops of the intervention may be consumed less in the farming household, so that more can be sold for profit. This happened in the case of a milk production scheme in India, where households in milk cooperatives drank *less* milk than those without a cooperative [4]. How additional income is spent when food purchases account for 75-80% of household expenses, as it is among the ultra-poor, has important health consequences [22]. "Lumpiness" of income (whether it is sporadic, large payments or more consistent) and intra-household control of income affect how it is spent [199]. So when cash cropping schemes increased household income without significantly affecting child nutrition [51, 284], in the 1990s agricultural programs began targeting women and aiming to address micronutrient deficiencies, many through home gardening projects [298]. During this time, evidence on the women's empowerment and home consumption pathways proliferated.

A large body of evidence has shown that when **women control income and**

resources, there is a stronger effect on household wellbeing than if men control those same resources [210, 129, 183, 209, 242]. The impact of women's control of income on child nutrition is strongest in lowest income groups [298]. Relatedly, women's nutrition knowledge and decision-making power is an important mediator between household wellbeing and child nutritional status [298, 242, 104]. With more decision-making power, a mother is more likely to take children to clinics when they are sick, feed them foods she believes are best for their health and nutrition, and give other optimal care behaviors. A high quality diet accessible at the household level does not ensure adequate nutrition for young children [142, 192, 172]. Research revealing overweight (in caregivers) and underweight (in children) in the same households demonstrates the fallacy of equating household resources or available diet to adequate child nutrition [54].

While impacts of increased production and income on nutrition depend on a great number of factors, the **home consumption** pathway is the most direct route for agriculture to affect nutrition: growing crops increases farmers' access to the foods grown. Smallholder farmers depend on home production for much of their food consumption, so increasing the diversity of food grown may increase diet diversity. Interventions focused on foods that have a high demand elasticity among farmers, such as vegetables and animal-source foods, probably contribute the most to diet diversity. Many studies have shown increased consumption of vegetables as a result of home gardening programs [298, 244, 246, 67, 66, 105].

The 2000s have seen an increased emphasis on women as the key to food security, as well as the importance of combining agricultural interventions with **nutrition education** [298]. Households with more nutrition knowledge, independent of schooling, spend a greater percentage of their food budgets on micronutrient-rich foods, and this expenditure is relatively stable even as staple food prices fluctuate

[21]. Agricultural programs targeted at women, particularly those that include provision of nutrition information to women, seem to be more likely to improve nutrition outcomes [298, 125].

1.5 Under-recognized pathways from agriculture to nutrition

Three other pathways from agriculture to nutrition are apparent, but have not been emphasized in most agriculture-nutrition interventions or literature.

Firstly, **maintenance of ecosystem services** is critical to achieve nutritional impacts from agriculture in both the short and long term. As described above, soil fertility and integrity, pest biocontrol, and water resources are limiting factors to food production in sub-Saharan Africa. Agricultural interventions must improve or at a minimum maintain current levels of ecosystem services to have any hope of increasing productivity for small farmers.

Climate change is the most recently recognized threat to ecosystem services and agricultural productivity; a recent Lancet paper has identified climate change as the "biggest global health threat of the 21st century" [40]. It is predicted to cause a 3-7.5 percent reduction in cereal productivity in sub-Saharan Africa in the next 75 years [283], and 25-250 million Africans could suffer from climate change-induced water shortages [37]. Other estimates are even more dire, predicting a 25 percent fall in agricultural productivity in sub-Saharan Africa within the next 25 years as a result of climate change [35]. Climate change also threatens indigenous people who are dependent upon wild plants, animals, and predictable seasons for survival. Effects on infectious tropical diseases are also a potential factor in the ultimate impact of climate change on nutrition.

Agricultural strategies must be based on ecological approaches that take an active role in mitigating soil degradation, biodiversity loss, water resource declines, and climate change.

As agriculture provides the raw ingredients of aggregate food systems, which have profound impact on public health nutrition, agricultural policies and interventions should also take an active responsibility in creating **healthy food systems**. According to Pinstrup-Andersen, the goal of the food system is a healthy population [200]. Currently, agricultural policies in many countries help to create *unhealthy* diets. Incentives that are solely focused on grains and animal products can create imbalances that hasten the global trend to obesity and chronic disease. Tunnel vision on staple crops in agricultural programs and policies is not limited to developed countries; it is a guiding force behind agricultural development programs in developing countries as well.

Figure 1.7 shows the quantities of fruits, vegetables, pulses, cereals, and starchy roots available as food in sub-Saharan Africa from 1987 to 2003 [75]. Although quantities of cereals and starchy roots have increased over the years, quantities of fruits and vegetables have risen at a more modest rate, and quantities of pulses have remained very low. Increases in starches have been important, but there has been relatively little policy attention to increasing the availability of other dietary components. This oversight has limited opportunities to increase availability and reduce prices of nonstaples, which would make them more accessible to the poor.

Thirdly, **working with local pre-existing knowledge** in communities may be a critical modifier to enhance the effect of agricultural interventions on nutrition. Local knowledge is a valuable resource for agriculture-nutrition goals. Participatory research approaches in agriculture are useful in best identifying crops and crop varieties of greatest use to farmers [16]. Traditional ecological knowledge ("TEK")

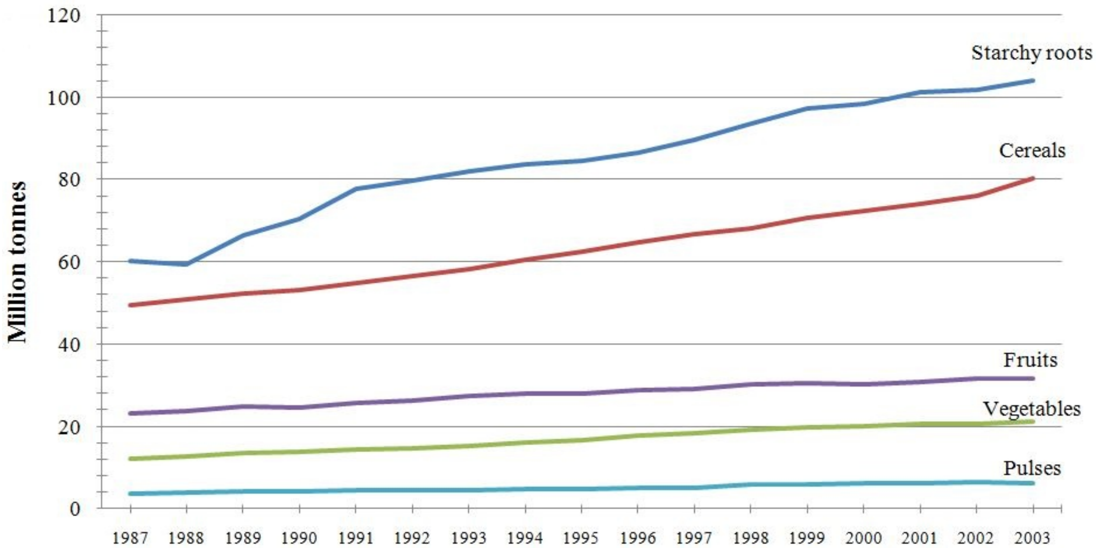


Figure 1.7: Food quantity trends in sub-Saharan Africa, 1987-2003 [75]

[111] may be vital in tailoring interventions to maintain ecosystem services. Public health and nutrition-oriented interventions could also benefit from identifying and working with local knowledge and practices, which can be more useful for health and nutrition than programs, policies, and popular culture assume [166, 144]. Traditional foods and knowledge of their use provide available, time-tested solutions to nutritional problems [119]. Agriculture and nutrition problems are complex enough that *all* available solutions should be collected and used where applicable. Validation of local knowledge also contributes to empowerment of communities to solve health and agricultural problems.

Figure 1.8 summarizes the pathways from agriculture to nutrition.

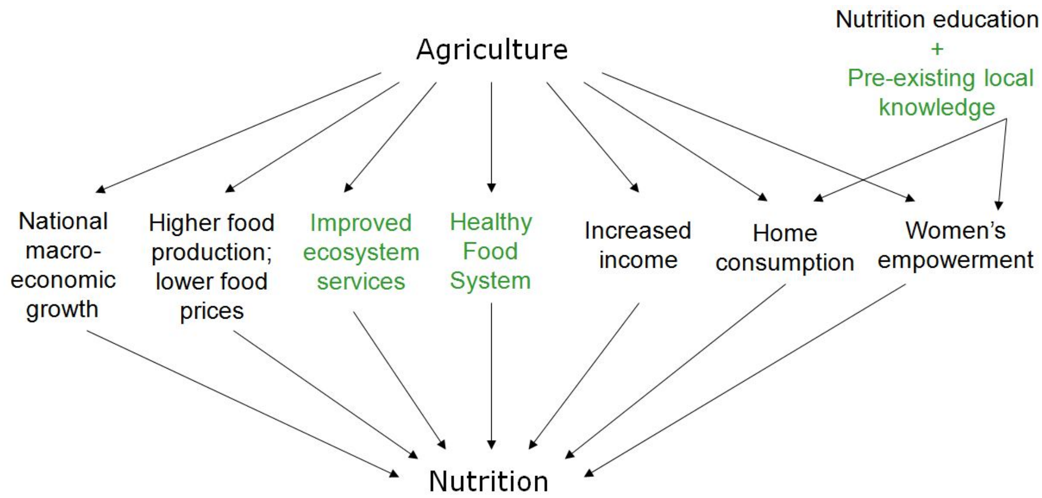


Figure 1.8: Pathways from Agriculture to Nutrition

1.6 The emerging imperatives

1.6.1 Solutions must help solve undernutrition while not worsening overnutrition

Agricultural interventions, which are often funded on the basis of their potential to improve food security, need to be designed with an updated understanding of the true meaning of food security as well as the nutritional trajectory of Africa. Several policy options can address the nutritional landscape of sub-Saharan Africa.

Research to Improve Productivity of Vegetables, Legumes, and Fruits

As shown above, the availability of fruits, vegetables, and legumes has barely changed from 20 years ago, while that of starches has increased. Increased investment in research and development of these so-called minor crops is one strategy to make them more competitive and easier to grow, so they are more attractive and rewarding for farmers. Improving farmers' access to seeds will also be important to encourage production of these crops.

Better Infrastructure to Enable Profit from More Perishable Foods

Producing cereals can be a practical choice for farmers with limited market access because cereals can be stored for longer periods than fresh produce. In some cases, farmers may be reluctant to produce crops other than cereals because without access to markets, they would be unable to sell the excess perishable crops. One case in northwestern Bangladesh showed that farmers who had been producing rice as a monocrop because of the dependable prices began producing fruits and vegetables as soon as a new bridge was built that would ensure rapid transport of these foods to Dhaka [175]. A persistent priority in improved food security is improving infrastructure and providing better access to markets.

Research and Programs to Use Underutilized Crops

One of the main reasons many well-adapted crop varieties and wild and traditional foods are underutilized in food security programs and undercounted in food security measurement is that they are not well understood. Mainstream culture tends to stigmatize traditional crops and wild foods, which are typically well adapted to local ecosystems. Cataloguing and research are needed to understand what food resources are available, their growth habits, and their nutritional value, which may be useful even for niche markets within mainstream culture [81, 122]. This work may help assuage the tendency to discard understudied traditional crops that could be important to food security for their nutritional value, environmentally sustainable production, and income-generating potential.

1.6.2 Food systems must maintain ecosystem services

Small farmers with few resources cannot be held individually accountable for producing a greater diversity of foods when it is costly to do so; it is the responsibility of governments concerned with food insecurity to create policies that support agricultural diversity and eliminate policies that create barriers to it. International multilateral and non-governmental organizations also have a large role in supporting agricultural programs through their programs.

Policies to Enable Diverse Production Systems

Multicropping can simultaneously reduce costs and increase productivity, which could reduce poverty and the desperation that drives natural resource degradation. Grain crops intercropped with beans often yield better than cereals alone: gains in cereal yields as high as 50-250 percent have been reported from intercropping with legumes in Malawi [159]. An average of 60 percent gains in maize yields, plus additional cowpea yield, were shown in a three-year maize-cowpea intercropping trial in Zimbabwe [87]. Case studies elsewhere demonstrated that rice-legume crop rotation reduced inorganic fertilizer use by 30 percent [196], and using legumes as green manure saved farmers 22 percent on production costs, in addition to increasing yields almost threefold [6]. Legumes can also significantly increase vegetable yield [159], possibly through their effects on soil fertility or other effects of diversity such as soil biota or pest biocontrol. In a review of 286 interventions in 57 countries using a set of resource-conserving agricultural practices including multicropping, the overwhelming majority showed increased yield, while also adding to ecosystem services through water use efficiency and carbon sequestration [207].

Although legumes stand out for increasing soil fertility and yields when they are used in crop rotations, in intercropping, or as soil amendments, legumes cannot be the only path to diversification. Gains from legumes are not automatic and require a base amount of soil fertility (phosphorus in particular) to effectively fix nitrogen. In addition, legumes are often susceptible to disease, and do not fix nitrogen well in acidic soils.

Beside legumes, mixed livestock-cropping systems foster nutrient cycling and productivity, as crop residues feed livestock and livestock wastes improve soil quality. Adding livestock to smallholder farms can have positive impacts on dietary diversity and nutrition as well.

Planting nonleguminous herbs can also increase productivity, either through soil fertility or pest resistance, the effects of which are often difficult to distinguish in field settings. Farmers in Uganda observed that soil fertility and nematode resistance increased when they planted amaranth in their tomato fields [97]. Marigolds, onion, and garlic can function as pest deterrents when planted around vegetable fields. Furthermore, diverse plant species provide habitat to many insect species, increasing the potential for biocontrol of pests and creating safe havens for pollinators.

Governments, multilateral institutions, and nongovernmental organizations (NGOs) all have a role in generating food security projects that enable diverse production systems. Agricultural program priorities and extension staff at least should not actively discourage farmers from growing a variety of foods, nor in most cases should farmers be given advice and incentives to convert the majority of their cropland into single staple crops. Efforts to incorporate traditional crops and local varieties into standard agricultural and health extension training is one way to recognize and promote traditional systems important to food security. More research is needed on the potential agronomic and nutritional gains from planting variety mixtures within the same crop, but given the available positive evidence [78], policies to make planting variety mixtures as easy as monocropping may be the step most needed now. Such policies could include legalizing the sale of mixed seed or funding breeding programs to maximize yield from variety mixtures [77].

Conservation of Crop Varietal Diversity

Within-crop diversity (many varieties of the same crop) is arguably as important to food security as between-crop diversity, because it allows a species to survive in varied environments, owing to the ecosystem service of genetic diversity. Low genetic diversity in farmers' fields presents the risk of catastrophic crop loss; it also lessens the chance of future productivity if crop varieties cannot be found to overcome pests or other stresses wrought by climate change. Following the exemplar of Nikolai Vavilov, who in the first part of the 20th century traveled the world collecting seeds and documenting crop diversity to quell famine [179], plant breeding authorities continue to recognize that, "Plant genetic resources represent both the basis for agricultural development and a reservoir of genetic adaptability that acts as a buffer against environmental change. The erosion of these resources threatens world food security" [62].

Farmers in the Central African highlands plant bean variety and species mixtures to tailor their crops to specific growing conditions [260]. Sociocultural reasons may also result in continued cultivation of several varieties; the pattern of maize diversity in Mexico differs significantly between ethnic groups beyond what would be expected from varying agroecosystems [25], indicating that varietal diversity plays a role in satisfying food preferences.

Environmental and genetic diversity also increase nutritional variation between crop varieties, providing a larger smorgasbord from which to meet dietary needs. Recent research has uncovered as much as 33-fold differences in micronutrients and known health-promoting phytochemicals between varieties of maize, wheat, onions, bananas and apples [96, 1, 302, 61, 154]. Rather than a cue to breed lines with the highest content of each known health-promoting compound, the evident diversity between varieties is a reason to grow and consume many different varieties, to ensure intakes of known and unknown health-promoting components. Science will surely identify additional benefits in years to come from as yet undiscovered phytonutrients. The only way to capture their benefits now is to rely on diversity.

Conserving genetic diversity within crops is essential to the goal of supporting agricultural diversity. Genebanks serve a critical function of ex situ crop variety preservation, so that varieties can be given out, regenerated, and used in breeding new varieties. In situ conservation is also important because it allows continuous adaptation of crops to new environmental surroundings. Conservation strategies agreed upon in the 2001 International Treaty on Plant Genetic Resources for Food and Agriculture should be incorporated into overall food security policies [38].

Indicators of Ecosystem Service Impacts of Production Systems

Collecting information on the impact of producing and transporting food on ecosystem services may guide food security policies in a different direction than at present. Indicators of the impacts of production systems on ecosystem services would allow governments to prioritize, through incentives or other policy instruments, those systems that best maintain ecosystem services and to realize benefits to food security from doing so. Such indicators are needed to hold governments accountable for their agreements on food security and sustainability. Many of these indicators are not yet well developed enough to use for policy decisions, so research is needed to develop simple, reliable indicators for estimating production impact on ecosystem services.

"Crop per drop" - yield obtained per amount of water used-is one such indicator. Soil nutrient costs per hectare (in the absence of fertilization) is another useful ecological indicator that could guide crop choices by indicating soil productivity gains or losses from production of specific crops, individually and in combination. Food miles also has been suggested as an indicator of fossil-fuel use linked to climate change, although total fossil-fuel use in production, not just that linked to transportation, is a better indicator [208, 238]. These indicators would be useful for generating policies that factor in externalities to bring food production more in line with conservation of ecosystem services.

Beyond tracking the productivity of individual crops, it would be useful to understand their productivity when planted together, and more regularly using an indicator of combined yield per hectare or land equivalent ratios (LER). Such an approach is important in sub-Saharan Africa, where many smallholder farmers grow complex polycrops to reduce risk and maximize use of land, nutrients, and water [87]. More research to understand the interactions between crops and their effects on productivity can help extension efforts in Africa promote the most practical, productive cropping practices. Research can also endorse the notion that polycropping and crop rotation are rational and forward-looking means of generating food security rather than undesirable coping strategies.

1.7 Shift to Global Nutrition

Within the past five years, international health has shifted to global health. Brown et. al write that "'Global health,' in general, implies consideration of the health needs of the people of the whole planet above the concerns of particular nations" [24]. Further, it reflects a shift from the concept of (usually Northern) health professionals working internationally, to a situation where solutions must come from global perspectives and a diversity of experience, expertise, and political will.

Likewise, it would seem that "international nutrition" ought to transition into "global nutrition," to reflect the global interconnectedness of food and health systems. Global nutrition includes the understanding that food systems interventions have far-reaching consequences, both over time in individual lives, and over geography in a world connected by atmosphere, travel, media, and trade. This is becoming increasingly clear with climate change, as well as for consequences on water, biodiversity and cultural diversity, each with effects on nutrition. Every smallholder farmer is a participant in the global food system; what they produce affects the food and ecosystem services available for their household, their region, their country, and the world. No food system or environment is isolated from the rest of the world, and agriculture, food, and health solutions come from all cultures.

1.8 Preface to following chapters

Within the paradigm of global nutrition laid out in this chapter, each subsequent chapter examines a piece of the emerging imperatives of global nutrition.

Chapter 2 outlines the nutritional situation of Kenya and Tanzania, and how the Traditional Foods Project, an intervention to promote production, marketing and consumption of traditional African vegetables, offers multiple possibilities to ameliorate nutritional problems and their underlying causes. The conceptual framework for how the program might affect farmer diet and nutrition, and the methods for evaluating those pathways, are laid out. The second part of Chapter 2 presents results about program implementation, uptake, and retention. Understanding who chose to participate and stay in the program, and what activities were delivered and how, puts into context subsequent chapters that evaluate impact.

Chapter 3 presents an evaluation of whether the program, either directly or through its main hypothesized pathways, influenced the outcome of TAV consumption in farmer households. This is critical for understanding how farmers' production and knowledge affect nutrition-related behavior surrounding traditional foods.

One of the factors which was unexpectedly important in predicting change in TAV consumption was farmers' knowledge of how TAVs could be used to prevent or treat disease. Chapter 4 presents in-depth data about the link between knowledge of medicinal use of TAVs and TAV consumption as food - illustrating a connection between biocultural diversity and nutrition.

Chapter 5 presents an evaluation of whether the program in Kenya, primarily through its main goal of increased TAV production, affected farmer household diets through direct consumption of vegetables, increased incomes, or increased women's control of income. This chapter examines the well-established routes from agriculture to nutrition in the case of a potential niche crop that could be marketed in the context of the nutrition transition.

One of the links between TAV production and diet suggested in Chapter 5 is that increased farm crop diversity may be associated with TAV production. Chapter 6 seeks to address the question of how crop diversity is related to nutrition, using data from both Kenya and Tanzania. Agroecological literature has long discussed and promoted crop diversity for production and preservation of ecosystem services - this chapter shows a potential link with nutrition.

One critical ecosystem service for human food security and nutrition is biodiversity, including genetic diversity within crops. Chapter 7 is the first paper of its kind, which tests whether there may be a relationship between varietal diversity within a crop and consumption of that crop.

Chapter 8 draws together the conclusions of all chapters, discussing how they relate to each other and to the emerging imperatives for global nutrition.

CHAPTER 2

TRADITIONAL FOODS FOR WEALTH AND HEALTH: DESIGN, EVALUATION, ADOPTION, AND DELIVERY OF A PROGRAM PROMOTING TRADITIONAL AFRICAN VEGETABLES AMONG SMALLHOLDER FARMERS IN KENYA AND TANZANIA

2.1 Introduction

The aim of this paper is to:

1. Describe the rationale and design of a program promoting traditional African vegetables (TAVs);
2. Describe the aims and methods of the program evaluation (impact and process);
3. Present evidence to evaluate program uptake, continuation, and delivery.

2.1.1 The context

Sub-Saharan Africa has a seemingly intractable problem of poverty and malnutrition. The Millennium Development Goals call to reduce by half the proportion of people living on less than a dollar a day, and to reduce by half the proportion of people who suffer from hunger [263], but Africa is far from meeting those targets. In East Africa, levels of child stunting have stayed constant at 44% since 1990 [264].

National nutritional studies indicate that stunting affects 35.8% of children under 5 in Kenya and 44.4% in Tanzania; 16.5% of Kenyan and 16.7% of the Tanzanian children are underweight [292]. Hidden hunger is a problem as well. In Kenya, an estimated 70% of children under 6 have sub-clinical vitamin A deficiency and 60% have iron-deficiency anemia. In Tanzania, vitamin A deficiency prevalence in young children is 37%; 65% of Tanzanian children have iron-deficiency anemia [271].

A very different situation is found among the middle and upper classes in urban areas of East Africa. As is happening in low and middle-income countries around the world, a nutrition transition is occurring, marked by a shift to a diet high in sugar, fat, refined carbohydrates and processed foods and an increase in overweight, obesity and related chronic disease such as diabetes, hypertension, and cardiovascular disease [58, 204, 206]. As of ten years ago, adult overweight exceeded underweight in both countries, in both urban and rural areas [168]. Although current data on obesity rates are unavailable, data from other regions of sub-Saharan Africa show rapid increases,[1][141, 23] and urbanization, a strong indicator of the nutrition transition [205], has increased in both countries. Diabetes and hypertension have increased in Tanzania, especially among the middle and upper classes [160]. These countries suffer from what can be called the "triple burden" of malnutrition: protein-energy malnutrition, micronutrient malnutrition, and overconsumption [199].

This study took place in two areas in Kenya in Tanzania where this "triple burden" exists: rural areas surrounding the large urban centers of Nairobi and Arusha. Kiambu is a district made up of mostly rural and some peri-urban areas, just north of Nairobi, and Arumeru and Arusha districts surround the city of Arusha, Tanzania (see Figure 2.1. About 22% of Kiambu District residents are below the Kenyan poverty line of \$0.53/day [137], and 18% of the population in the Arumeru District earned less than Tanzania's very low poverty line of \$0.26/day [214]. A third of the population in Arusha Region (which includes Arumeru) are

[1]In West Africa, prevalence of adult overweight rose by 25-72% between the early and late 1990's, even though prevalence of child underweight did not change significantly in the same period [141].

food insecure [275]. Inequality is large between peri-urban and rural areas. The poor are disproportionately rural: in Kenya, 84% of all poor and 92.3% of the ultra-poor are rural residents, although only 79% of the total population is rural [138].

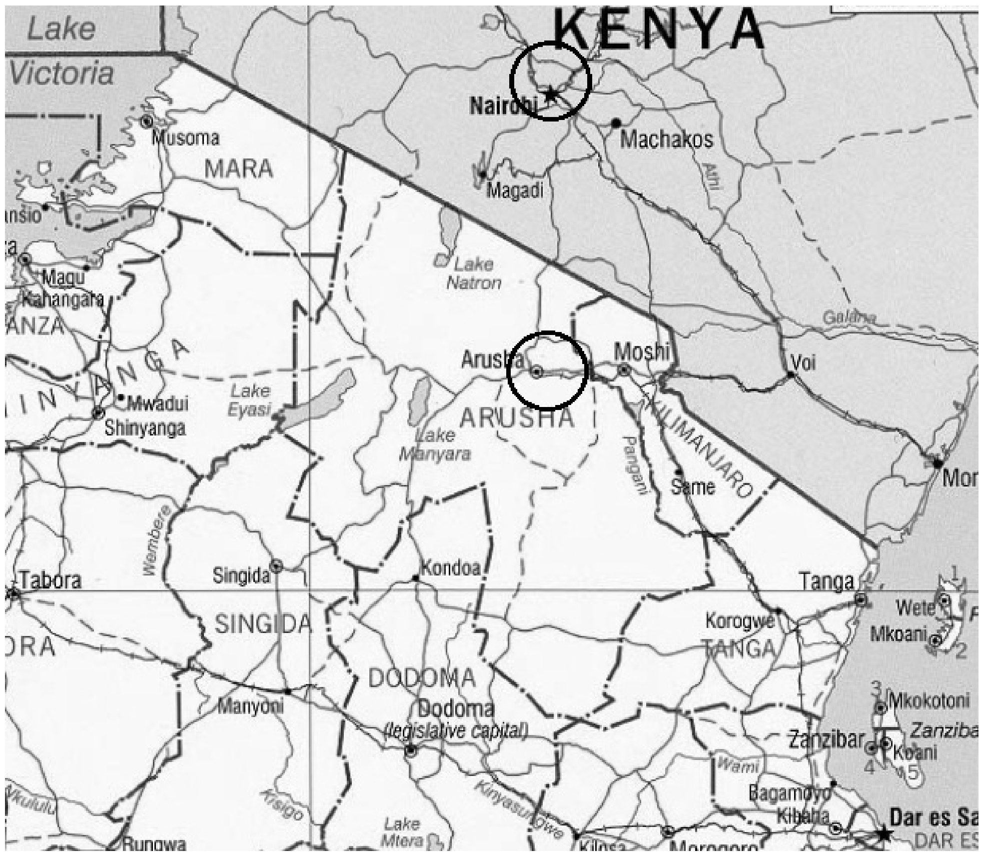


Figure 2.1: Map of study sites in Kenya and Tanzania [288]

In the rural areas of these districts, smallholder farmers make up the majority of the population. Nationally in Tanzania, over 2/3 of the rural population works full time on the farm, but in Arusha Region, this figure is 90% [275]. Most smallholder farms in the study region are integrated crop-livestock systems with maize and beans as the staple crops for home consumption; many have considerable experience in vegetable production. Agro-ecological conditions in Kiambu and Arusha are similar with high rainfall and mountainous topography, although

Kiambu is higher in altitude and cooler, and Arusha has more marked rainy and dry seasons. Each of these subhumid areas is favorable for vegetable production, but suffers from low soil fertility from soil erosion due to hilly terrain and seasonal heavy rains, where ground cover is inadequate. Inherited landholdings have shrunk in size over the years in both places, due to population growth, making constant production necessary and nutrient mining a risk for continued crop productivity.

These areas, with agronomic potential and available markets in urban centers, have the resources that can potentially support adequate livelihoods. Most farmers in these areas produce crops for sale, but struggle with uncertain marketing prospects and poor links with markets. Their resulting low incomes, combined with production that does not meet household needs, puts small farming households at chronic risk of malnutrition.

2.1.2 Food-based solutions and agriculture-nutrition links

Given this situation, food-based solutions are ideally suited to alleviate poverty and malnutrition in Kiambu and Arumeru. Even with their relative proximity to urban centers, rural farmers have low processed food consumption and limited access to health services, reducing the effectiveness of food fortification and supplementation as strategies to reduce micronutrient malnutrition. They do, however, have land and labor with which to grow food. Agricultural production can provide income, food, and nutrients, and thus alleviate micronutrient malnutrition through dietary diversification. A better-nourished farmer, in turn, has the potential to produce more food.

Food-based solutions are also essential for curbing the nutrition transition. The nutrition transition is fundamentally due to a sub-optimal food system, marked by high availability of cheap fats, sugars, and refined grains, and low availability and accessibility of fruits and vegetables. Individual food choices certainly play a role, but food choices are never made in situations of perfect free choice: what people eat depends to a large extent what is available, accessible and culturally desirable. Migration studies showing that people adopt diet patterns, and related health or disease profiles, of their new culture within a generation indicate that the food system and eating norms in which people live are the primary factors determining their food choices [91, 225, 84]. The WHO estimates that 2.7 million deaths a year are attributable to low fruit and vegetable consumption, putting it among the top 10 global risk factors for mortality [290]. The WHO/FAO put forth a minimum requirement of 400 grams of fruits and vegetables a day per person [294]. FAO food balance sheets indicate that total quantities of fruits and vegetables available for human consumption in Kenya is about 280 grams per capita per day [75]. For Tanzania, only about 150 grams of fruits and vegetables are available per capita per day [75], less than half the recommended amount. These deficits exist although the countries have an environment well-suited to produce fruits and vegetables. Increasing the supply, as well as the demand, for vegetables is important for public health in developing countries.

The coexistence of poverty and risk of malnutrition among smallholder farmers, and increasing obesity and chronic disease in the population, illustrates the need to improve the food system to better nourish the entire population. Human nutrition is the starting and ending point for food systems, and the goal of the food system, according to Pinstrup-Andersen, is a healthy population [200].

There are several well-identified pathways from agriculture to nutrition [298]. Macroeconomic growth and increased national food availability are long and untargeted routes to affecting nutrition in small farmer households. Increased household income is important, but does not guarantee that all members of the household will be food secure or well-nourished; it depends on who controls the income, how it is used, how often it is received (continuously or in large lump sums). Home production of food is also important, practically speaking, for small farmer households who are often far from markets. Education can potentiate the impact of income and home production, by helping farmers to choose crops, foods or strategies that can best maximmize available resources for child nutrition. There is also a need for agriculture to support ecosystem services such as soil fertility, water availability, pollinator habitats, pest biocontrol, and genetic diversity in order to ensure high productivity of crops. Finally, every farmer has some role in the aggregate food system, and the kind of crops grown determine the food available to the population. Agricultural policy and rural development programs drive crop choice to some extent, and public health should have some role in policy and programmatic choices. Subsidizing and promoting only a few limited crops, including those important for production of refined carbohydrates and unhealthy fats or biofuels, contributes to global nutritional problems.

One potential intervention to improve nutrition on both ends of the nutritional status spectrum, and to improve ecosystem services, could be to encourage crop diversification among smallholder farmers including traditional crops. Traditional African vegetables have been found to be micronutrient-dense and as they are highly adapted to the agroecosystem, and they require few inputs to grow.

2.2 Traditional Foods Project design

The Traditional Foods (TF) Project is a three-year program (2007-2010) in Kenya and Tanzania, conceived and implemented by a Kenyan non-profit organization Farm Concern International (FCI), the International Potato Center (CIP), The World Vegetable Center Regional Center for Africa (AVRDC-RCA), and Urban

Harvest. (The roles and capacity of each organization are described in *Appendix A*.) The goal of the TF Project was to enhance market access, income, and nutrition among smallholder farmers (farming less than two acres of land) through increased production, marketing, and utilization of traditional African vegetables (TAVs) and orange-fleshed sweet potato (OFSP). As such, the tagline of the TF Project was "Traditional Foods for wealth and health." The program operated in four sites: Kiambu District (environs of Nairobi, Kenya), Arumeru District (environs of Arusha, Tanzania), Busia (Western Province, Kenya), and Kabondo (Nyanza Province, Kenya). Due to consideration of agronomic characteristics of each site, the intervention in Busia and Kabondo focused on OFSP production, and TAV production in Kiambu and Arumeru. Therefore only Kiambu and Arumeru are included in this study about TAV production.

2.3 Program goals and main activities

The program has four main pillars: increasing TAV production, formation of farmer groups to link farmers to buyers, nutrition-focused marketing of TAVs in urban markets, and campaigns to increase awareness of nutritional value of TAVs among farmers.

Activities to increase production included agronomic training and improving reliable access to high-quality seed through demonstration plots, direct seed distribution, and engagement with urban commercial seed multipliers who could be long-term seed suppliers.[2] Project staff held specialized trainings and farmer field days on TAV production techniques, based on improved production practice infor-

[2]This meets not only the objective of developing a reliable seed source for TF Project farmers, but also an objective of particular importance to Urban Harvest, of training urban farmers to run commercially viable seed enterprises for improved livelihoods. Vegetable seed production provides an opportunity for urban farmers, since consumers fear wastewater farming in urban-produced produce which limits sales expansion of the vegetables themselves.

mation supplied by AVRDC.

The Project aimed to increase marketing through a "Commercial Village" approach, which joins together 300-500 farmers to coordinate production, sales, and input-sourcing. Commercial Villages are made up of multiple "marketing support units" of 20-25 members each. This system builds on the traditional social structure of African villages to create socially viable commercial entities that increase smallholder farmers' market access, bargaining power, and credit worthiness while reducing transaction costs. Program staff trained farmer groups to build capacity, using 15 modules refined during the pilot phase of the project; a list of the training modules is in Appendix A. Program staff also worked to establish market linkages between Commercial Villages and other players in the TAV value chain (seed stockists, transporters, traders, and buyers at formal and informal markets). In order to impact income, the outcome goal was to develop production and marketing plans, outlining market destinations and quantities to be harvested each day, and to set up bulking points, a central point in each village where buyers would collect produce. A first step, along with group training on market-oriented production and record-keeping, was to facilitate farmer field visits to successful commercial villages in Kenya.

Increases in production and marketing were to be bolstered by an image-building campaign to promote demand for TAVs based on their nutritional and "heritage" qualities. Market research prior to the project indicated that upper class consumers lacked awareness of TAVs but expressed a desire to buy foods to improve health, and lower class consumers said that unavailability was the main constraint to consumption. Program activities included special TAV promotion weeks in Nairobi supermarkets and Arusha outdoor markets, eye-catching market labels and recipe cards for market displays, and field days in more peri-urban areas.

Future radio and TV promotions were planned.

To promote interest and consumption among farmers, the program staff consistently stressed the nutritional value of TAVs for home consumption in all program visits. Groups also received at least one training dedicated to the actual nutrient content of the vegetables, the health effects of each nutrient, and preparation techniques to retain nutrients. Farmers were also given pamphlets about the nutrient values of the TAVs. Program staff were attentive to local knowledge about health value of the vegetables, including medicinal uses, which farmers shared with each other during nutrition trainings.

A program logical framework is provided in Appendix A.

2.3.1 Why traditional leafy vegetables?

The target crops of amaranth (*Amaranthus* spp.), nightshade (*Solanum americanum, S. scabrum, S. villosum*), spider flower plant (*Cleome gynandra*), cowpea leaf (*Vigna unguiculata*), and sweet potato leaf (*Ipomoea batatas*) were selected based on their nutritional qualities and their ability to give smallholder farmers a competetive advantage in supplying urban markets.

TAVs are excellent sources of micronutrients (see Table 2.1). All of the five TAVs promoted are very high in iron, made more bioavailable by high vitamin C content in amaranth, cowpea, and sweet potato leaf. They are high in pro-vitamin A, and TAVs are almost always cooked with carrots and oil, which further increases the pro-vitamin A content and bioavailability of a TAV dish. One study showed that feeding 30 g cooked amaranth to school children every day over two months significantly increased serum retinol (+14.8 $\pm$ 1.6 μg/ml) and hemoglobin (+2.2 $\pm$ 0.6 g/ml) concentrations [50]. As determined by data collected in this study, preschool-age children in the study sites in Kenya and

Tanzania typically consumed 66 g (raw weight) of TAVs on average per sitting. The TAVs are also a significant source of calcium, zinc, and folate. Studies measuring nitrate and oxalate contents of a number of amaranth varieties and found that the presence of these compounds was not high enough to affect calcium and zinc bioavailability [49]. TAVs have been shown to contribute to iron, zinc, and vitamin A requirements in Tanzania, especially for the poorest segments [289]. In all, they are more nutritious than more commonly eaten cabbage and even kale. They are used as an accompaniment to maize meal (ugali), so including more of them on the plate may increase caloric intake by improving palatability of the meal, although the vegetables themselves are low in calories.

TAVs do not require large input costs. TAV production costs are low compared to alternative crops where they are grown; pests and diseases are few, especially compared to exotic vegetables like kales; planting and harvest times are flexible, and maturity rates are fast (farmers start harvesting TAVs within 1-2 months). Flexible planting times and fast-maturity are important characteristics in a food insecure context, both for cash and for direct food consumption. High genetic variation among TAVs [176] decreases risk, since large-scale blights or stress intolerance are unlikely.

TAVs are traditionally women's crops, meaning they are typically planted, tended, harvested, prepared and sold by women. Because of women's usual control over TAV production, decisions regarding their use, and income from their sale, the program theory predicts that increased production and marketing of these vegetables will yield increased empowerment and income available to women.

Cultivating TAVs is sustainable using very few inputs. TAVs are well-adapted

Table 2.1: Nutrient Composition per 100 grams of African Traditional Leafy Vegetables

Nutrient	Amaranth	Spider flower plant	Nightshade	Cowpea leaf	Sweet potato leaf	Kale	Cabbage	RDA children age 1-8
Vitamin A (μg RAE)	477	558*	306	664	490	769	9	300-400
Vitamin C (mg)	64	13	20	56	70	120	32	15-25
Iron (mg)	8.9	6.0	1.0-4.2**	5.7	6.2	1.7	0.59	7-10
Calcium (mg)	410	288	442	256	158	135	47	500-800†
Zinc (mg)***	0.4-0.8	0.2-0.5	0.2-0.4	0.3-0.6	0.2-0.7	0.4	0.2	3-5
Folate (μg DFE)	85			101	80	29	43	150-200

Sources: All data for TAVs are from the FAO Food Composition Table for Use in Africa [151] except where noted. Data for kale and cabbage are from U.S. Department of Agriculture (USDA) Agricultural Research Service, National Nutrient Database for Standard Reference, Release 20 [277]. All values are for raw vegetables.
RAE = Retinol Activity Equivalent. Conversion rate of 12 units beta-carotene for 1 unit retinol was used.
DFE = Dietary Folate Equivalent
†The value listed is an AI (Adequate Intake) rather than an RDA.
*Bioversity (IPGRI) data [33]
**Bioversity (IPGRI) data [60]
***AVRDC data [288]

to the local agroecosystem and usually require few chemical fertilizers and pesticides. Some reports have suggested that TAV cultivation improves soil fertility and/or nematode resistance, particularly when stems and roots are tilled back into the soil after harvest [97]. Cowpea is a dual-purpose crop, providing both beans and green leaves, which could be considered to be *triple*-purpose as it efficiently fixes nitrogen, which is often a limiting nutrient in African soils.

The **marketability of TAVs** was an important feature for its selection as a target crop for income generation. Owing to TAVs' short maturation period, continuous production for high-value formal markets is possible. Recent studies on TAVs in East and West Africa have indicated that high unmet market potential of available traditional vegetables and predict media efforts could boost sales [83, 289]. A large potential market for TAVs in urban areas is characterized by increasing consumer demand for "functional" foods [285]. TAVs are rich in micronutrients, antioxidants, other health-related phytochemicals; amaranth and sweet potato leaf may lower cholesterol [203, 112], nightshade is commonly believed to control high blood pressure and diabetes [60, 220, 131], and spider flower plant is used to control inflammation [33]. However prior research in Tanzania showed that as wealth increases, TAV consumption decreases [288, 289]. A continued challenge is to reverse the prevalent image of TAVs as "poor people's food," through marketing TAVs as a functional food to a niche market of upper class consumers.

Finally, **TAVs are traditional foods in Kenyan and Tanzanian culture**. Most people in the study areas, no matter what class, have childhood memories of their grandmother or mother serving them TAVs. A leftover colonial mindset that labeled wild-gathered foods as primitive, pressures to compete globally, as well as shrinking landholdings due to population growth, have led to a reduction of land used to grow TAVs [163, 211]. These foods fit into a decades-long process of rediscovering cultural identity after colonial times, and retaining it within the context of cultural changes due to globalization. Traditional food culture has been associated with fewer negative health consequences than would have otherwise occurred due to a nutrition transition [123].

Because of these attributes, TAVs have a high potential to improve diet and nutrition of smallholder farmers.

The TF Project attempted to scale up a pilot project, which FCI implemented from 2003-2006 and which was highly successful at increasing farmers' production and sale of TAVs in Kiambu. The main results of the pilot project are included in Appendix A.

Qualitative farmer discussions suggested diet and nutrition impact from FCI's pilot project, but the lack of formal assessment leaves questions about whether the TF Project, as an expansion of the pilot project, can deliver diet and nutrition benefits to farmers.

2.4 Specific aims of the impact evaluation

According to the TF proposal, the evaluation needs to capture not only the impact, but the process by which that impact works. This involves two angles: testing program theory (program impact pathways) and assessing the process of program implementation (delivery). The specific aims for the impact evaluation were to evaluate both the direct impact and the pathways through which impact may occur.

1. **Direct impact:** Does diet change, related to program participation?

    Aim I: To show whether household and preschool child diets change based on one year of participation in the agricultural intervention.

2. **Program impact pathways:** Does overall diet and TAV consumption change, related to specific program outputs?

    Aim II: To investigate the relationship between level of production and marketing of target crops and household and preschool child diet, and how it is modified by women's control of income.

Aim III: To link farmer attitudes and knowledge about target crops to their consumption, and show if this relationship changes after the intervention.

The principle hypotheses to be tested are:

1. If production of target crops increases, those crops will be eaten more frequently in farmer households, including by children age 2-5 years.
2. The more farmers know about nutrition/health benefits of the target crops, and the more positive their attitudes are about them, the more they will eat of them.
3. If production and marketing increase, farmers' income from target crops will increase, which will increase net income and result in diversified food purchases.
4. Overall household diet and diet of children age 2-5 years will improve if production and marketing of target crops increases.
5. The impact of increased production and marketing of target crops will be influenced by women's control of income and decision-making.

2.5 Process evaluation

The expectations and explanations for the impact evaluation questions (above), rest on program implementation: what was actually implemented, to what extent, when, how, and who participated? Key research questions to the process evaluation include:

a) Adoption: who participated, and what factors were related to farmers' decision to join the TF Project?

b) Continuation: what factors were related to farmers' continued participation in the TF Project vs. stopping activities?

c) Delivery: what was actually implemented, to what extent, when, how, and what factors were related to that?

2.6 Long-term goal

The long-term goal of this research is to understand how agricultural programs, particularly those involving traditional food crops, can affect child nutrition, and to make policy recommendations for implementing programs that improve nutritional wellbeing of producers. This requires an understanding of how programs are implemented, in addition to assessment of how program theory may be related to targeted outcomes, regardless of how well any particular program is implemented.

2.7 Conceptual framework

A conceptual framework illustrates the hypothesized pathways through which an increase in production, marketing, and knowledge of TAVs within the context of TF Project participation could influence household and child diet, in the context of other important variables that may affect the basic relationships laid out in the principle hypotheses (Figure 2.2).

It is hypothesized that participation in the TF Project increases level of production of TAVs, which will lead to greater access to these vegetables at the farm level and **increased household and child consumption** of them (hypothesis 1). Another way that increased consumption of TAVs may be encouraged is through **education** about the nutritional qualities of TAVs to farmers, combined with general TAV marketing campaigns, which may change **attitudes** (hypothesis

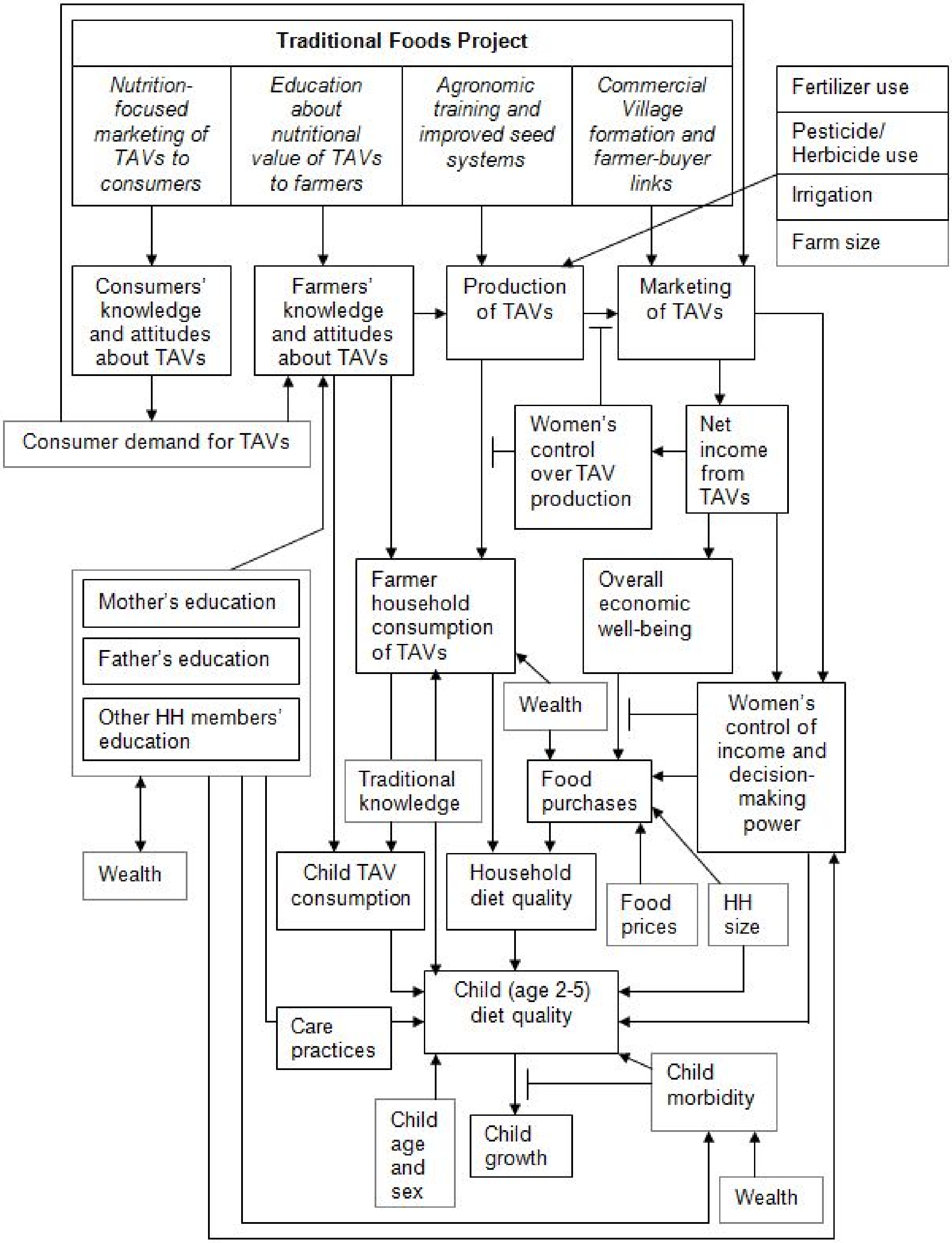


Figure 2.2: Conceptual Framework

2). Increases in marketing associated with the TF Project are hypothesized to increase farmers' **income**, and lead to increased and diversified food purchases (hypothesis 3). Given these pathways, household and pre-school child diet quality may improve (hypothesis 4), depending on **women's income control and decision-making power** (hypothesis 5). Marketing of TAVs is likely to itself increase control of income and decision-making power by women, since TAVs are crops typically farmed by women; alternatively, it is possible that as TAVs are sold through more formal marketing channels and generate more income, they will become controlled by men and women's income and decision-making power over their production and use will decrease.

The conceptual framework is helpful in laying out the variables for which data need to be collected, as well as the relationships between the variables. As such, the conceptual framework guided the data collection instruments and data analysis.

2.8 Evaluation design

A pre-post intervention design with a comparison group was used to assess program impact, using data from the TF Project participants and non-participants. A baseline survey was done immediately following recruitment of households into the TF Project, and a follow-up survey was administered to the same households one year after baseline. A formative research phase informed the creation of the household survey. Data from participants and non-participants in program villages were used to assess program adoption. Survey data were also used to assess program implementation. Focus group discussions and observations added important qualitative information to analyses of impact and implementation.

2.8.1 Formative research

A formative research phase took place from January-August, 2007. From January-June, a literature review and initial program theories were developed. From July-August, rapid appraisal techniques [231] were used to understand the situation in Kenya and Tanzania. **Interviews, focus group discussions, and direct observation** were used to learn about the context, values, and assumptions surrounding production, marketing, knowledge, attitudes, and consumption of TAVs, as well as typical diets, health and nutritional status in the study areas.

This understanding was gained through interaction with four groups of people:

1. Staff at the partner institutions were managing and implementing the TF Project: CIP, AVRDC-RCA, FCI, and Urban Harvest.
2. Vegetable farmers in the study areas, including some who had participated in the pilot project run by FCI, and some who had not.
3. Vegetable sellers and buyers in outside markets, supermarkets, and hotels.
4. Local public health workers, including government and hospital nutritionists, nurses and community health workers.
5. Staff at other NGOs operating in the study areas.

The main purpose of the formative research was to develop a conceptual framework (Figure 2.2), and to formulate a survey that could efficiently gather the data needed to test that program theory. The general findings of the rapid appraisal are shown in Appendix A.

2.8.2 Household survey

A household survey was administered to 360 farmer households at baseline (October, 2007); 180 households in Kiambu, Kenya, and 180 households in Arusha, Tanzania. The same households were followed up one year after baseline (October, 2008).

Writing

The household survey producer questionnaire was developed according to the conceptual framework (Figure 2.2), and knowledge gained from the formative research phase. Each concept present in the conceptual framework was operationalized into one or more indicators that could be measured using questions in the baseline questionnaire. The questionnaire was used to gather information on household demographics, assets, income sources, agricultural production (particularly focused on the target crops), gender and decision-making, diet, nutrition knowledge, knowledge and attitudes about the target crops, and child age, weight, and morbidity. The questionnaire can be found in Appendix A.

Construct Measurement

The main exposure variables in this study are TAV production, TAV marketing, nutrition knowledge about TAVs and attitudes about TAVs. These and other intermediate outcomes are defined in Table 2.2

Table 2.2: Construct measurement

Construct	**Definition and method**	**Range**
TAV consumption	Whether or not TAVs were consumed	0/1
	Number of days TAVs were consumed in a week, using validated HKI 7-day FFQ	0 to 7
	Number of TAVs that were consumed at all during the week	0 to 5
	Mean grams of TAVs consumed per day by children age 2-5 years, estimated using a standard bowl	0 to ∞

Table 2.2 (continued)

TAV production	Whether or not TAVs were planted Number of TAVs planted Amount harvested (kg) per 6-month season of long rains (April-Sept)	0/1 0 to 5 0 to [amount equivalent to 4x published yields (tons/acre)]
TAV marketing	Amount sold (kg) per 6-month season of long rains (April-Sept) Number of markets where farmer sold TAVs	0 to [amount equivalent to 4x published yields (tons/acre)] 0 to 4
TAV income	Gross income from the sale of TAVs over the 6-month season (April-Sept) Net income from the sale of TAVs over the 6-month season (gross-input costs) Percent of gross income that women keep	0 to ∞ 0 to ∞ 0 to 100
Nutrition knowledge	Score based on responses to 4 survey questions: 1. listed any TAV as a source of vitamin A 2. in addition to #1, listed a specific function of vitamin A 3. listed any TAV as a source of iron 4. in addition to #3, listed a specific function of iron	0 to 4
Medicinal knowledge	Number of unique illness reported to be treated with TAVs Whether or not household reported that it is possible to treat iron-related illness with TAVs	0 to 15 0/1
Attitudes about TAVs	Score based on responses to 3 survey questions 1. Do you want to eat (more/same/less) TAVs than you currently consume? 2. TAVs are not good foods for men (agree or neutral/disagree)	-4 to +3

Table 2.2 (continued)

	3. Do you serve TAVs to visitors? (yes/no)	
Wealth	Sum of real market values of 23 durable goods and livestock	0 to ∞
Livestock ownership in Cattle Equivalent Units (CEUs)	Number of livestock owned, expressed as equivalents to the monetary value of a cow, based on current livestock prices in each site	0 to ∞
Housing Quality Index	A factor analysis score representing housing quality based on roof, wall, and floor materials; higher numbers mean higher quality.	-1.86 to 2.15
Dietary diversity score (household): HDDS	Count of 12 food groups consumed by anyone in the household in the 24 hours prior to the survey, using a 24-hr recall technique for generating a food list*	0 to 12
Dietary diversity score (individual child age 2-5 years): IDDS	Count of 8 food groups consumed by the child in the 24 hours prior to the survey, using a 24-hr recall technique for generating a food list**	0 to 8
Dietary variety score	Count of all unique food items consumed in the 24 hours prior to the survey, using a 24-hr recall technique	0 to ∞
Number of fruits and vegetables consumed	Count of number of fruits and vegetables consumed in the 24 hours prior to the survey, using a 24-hr recall technique	0 to ∞
Number of vitamin A-rich foods consumed	Number of times food items containing $\geq 100\mu$g RAE/100g were consumed in the last week, using HKI 7-day FFQ	0 to 70
Number of iron-rich foods consumed	Number of times food items containing $\geq$ 1mg iron per 100g were consumed in the last week, using HKI 7-day FFQ	0 to 70
Women's purchasing decision-making power	Addition of responses to four questions: who decides about major new purchases & food purchases, and who pays for food & school fees	0 to 4

*HDDS Food groups: cereals; roots/tubers; vegetables; fruits; meat/poultry; eggs; fish; pulses/nuts; milk/yogurt/cheese; oil/fat; sugar/honey; miscellaneous.
**IDDS Food groups: grains/roots/tubers; DGLV; other fruits and vegetables; meat/poultry/fish; eggs; pulses/nuts; milk; oil/fat.

One of the main outcome variables in this study is dietary diversity. Dietary diversity indicates diet quality, and is operationalized as a household or individual **dietary diversity score** using a 24-hour food list. (See sections Q and R of the baseline questionnaire in Appendix A.) This study will quantify dietary diversity as the number of food groups out of a possible 12 or 8 consumed over the past 24 hours, using the FANTA Household Diet Diversity score (HDDS) and Individual Diet Diversity Score (IDDS), respectively [253].

There is widespread agreement on the value of dietary diversity, but there is a lack of agreement on exactly how to measure it. Diet diversity involves counting foods or food groups over a reference period; however food groupings, scoring systems, reference periods, whether to use cutoff points, and how to consider frequency of intake and/or portion size are all elements of diet diversity measurement on which no clear consensus has been reached [222].

The FANTA scores represent an effort to standardize diet diversity measurements across countries and experiments, and may be the most useful way to express the data, as other investigators begin to use the same measurement tool.

Portion size was not considered in the score because data on portion size were not collected. Theoretically, for a food to be counted as contributing to a food group, there should be some minimum portion size of it; for example milk in coffee or tea may not significantly contribute to nutrient adequacy. However basing a diet diversity score on a minimum intake of 10 grams in the Philippines resulted in only slightly higher correlation with nutrient adequacy than when portion was not considered [134]. Therefore lack of portion size may not pose a threat to validity of the measure [222]. This was observed to be generally true in the study sites, because there were no ingredients (other than salt, which is not part of the HDDS) that were typically used in minute quantities. Regarding milk in tea in particular, tea was an extremely common vehicle by which milk was consumed; the typical practice was to prepare tea in 50-100% milk, so when milk was consumed with tea, it was almost always a significant amount.

Child growth for children age 2-5 years was also measured as an outcome variable, by taking the child's weight at baseline and one year later. [3] Normal growth indicates macro and micronutrient adequacy, as well as good health (lack of disease) and care practices. It is unlikely that changes in child growth will be seen one year after baseline, due to the time it takes for the program to start. However, regression equations will examine the influence of program variables on growth. Furthermore, the measurement of growth at this and later time points during the program lifetime can be used to enhance knowledge of how agricultural interventions work, including how long it takes to see various household, diet, and nutrition effects, and which are seen first.

Pre-testing

After the questionnaire was drafted at baseline, it was pre-tested and revised with enumerator participation during enumerator training. Combining investigator and enumerator-led pre-testing, interviews with a total of 22 households informed the final version of the questionnaire. Revisions based on pretesting are summarized in Appendix A.

Enumerator recruitment and training

Enumerators for the household survey were recruited through advertisements in the locale of agricultural universities in Kenya and Tanzania. Six candidates were

[3] Weight was measured with Seca 840 digital bathroom scales. Accuracy of the scales was checked with a known 10 kg weight at the end of each day in the field.

selected for a week of paid training; at the end of training, four were selected to continue as enumerators for the survey. Training lasted five days and included an overview of the TF Project and its objectives, the purpose of program evaluation, an in-depth review of the questionnaire and the purpose of each question, role-playing, pre-testing, and participatory revision of the questionnaire based on pre-testing. The questionnaire greatly improved because of enumerators' questions and innovations.

Language of the questionnaire

The questionnaire was written in English, but administered in Kikuyu or Kiswahili in Kiambu, and in Kiswahili or Maasai in Tanzania. The enumerators generated vocabulary lists of crops in English and the local languages, as not all enumerators were familiar with all the crops grown. During role-play, enumerators practiced asking questions in the local language and in English, and checked whether they correctly conveyed the meaning of each question. For sections where wording would make a significant difference in the meaning of questions (such as sections O-P, Appendix A), enumerators debated among themselves and settled on the most appropriate way to ask the questions (in Kikuyu or Kiswahili), so that they would work from a common understanding. Research assistants, fluent in both English and the local languages, confirmed that the wording captured the meaning of the questions being asked.

Supervision during data collection

In each location, a research assistant was hired to lead the enumerators. In Kiambu, the research assistant was a previous CIP employee with years of experience in questionnaire administration and data entry. In Tanzania, the research assistant was a newly-hired AVRDC-RCA employee with international experience in agriculture research and questionnaires. The research assistants were responsible for answering enumerators' questions and making logistic decisions in the field, and checking questionnaires and correcting problem spots at the end of each day of data collection. A guide that research assistants followed to check common problem spots is included in Appendix A.

Special effort was given to ensuring data quality during the first week of data collection. The PI was responsible for data checking and continued training during the first week of data collection in Tanzania, and the manager of the TF Project in Kenya oversaw the first week of data collection in Kiambu, with daily phone contact to discuss progress and changes. Each day, the PI and the TF Project manager reviewed the completed questionnaires, and held a de-briefing session with enumerators. In this daily session, problems were discussed and strategies invented to correct problems in the future. The quality of the completed questionnaires improved markedly by the end of the first week of data collection. Based on common problem spots seen in the first week, a checklist was developed for checking questionnaires. By the end of the week, the research assistant assumed the authority for reviewing the questionnaires each day.

2.8.3 Sampling in the household survey

Sample frame

In the baseline survey, 360 farmer households were interviewed; 180 households in Kiambu, Kenya, and 180 households in Arumeru, Tanzania. At each site, 100 households were members of commercial villages in communities were the TF Project was taking place, and 80 households were non-participants in communities where the TF Project was not operating. It was important to select non-participating households from non-project areas because in the first year, the commercial villages could grow so that some non-participating farmers at baseline could be participants at the end of year one. For that reason also, a sample of 60 non-participant households within participant villages was selected only at follow-up in each site, to serve as a comparison group for predicting participation in order to understand self-selection bias.

There were four program and four comparison communities in each location, Kiambu and Arumeru; there were 8 program communities and 8 comparison communities altogether. In each of the 8 program communities, 25 households participating in the TF Project were interviewed (200 total). In each of the 8 comparison villages, 20 randomly selected households were interviewed (160 total). (See the chart below.) At follow-up, in program communities only, an additional 15 non-participating households were interviewed so analyses could be done to determine characteristics associated with program adoption.

	Program		Comparison		
Kenya	25	25	20	20	=180
	25	25	20	20	
Tanzania	25	25	20	20	=180
	25	25	20	20	
	=200		=160		

Selection of program communities

FCI selected the communities to target for participation in the TF Project. The criteria for selection of these communities included:

1. Size of farms: less than 5 acres (2.02 hectares), but large enough to grow 0.125 acre of TAVs or 0.5 acre of sweet potatoes
2. Experience within the community growing horticultural crops

3. Availability of labor
4. Existing or possible irrigation
5. Existing farmer groups
6. Access to markets (considering distance and road condition)

Four of the eight program communities already had participated in the FCI pilot project growing and marketing TAVs, and four had no prior contact with FCI.

Selection of comparison communities

Comparison communities were located in the same region as program-targeted communities, but were not among the villages considered and rejected for program participation. While program communities were selected on criteria important to the success of the *program*, comparison communities were selected on criteria important to the validity of the *research*. Extension agents who worked in the program-targeted communities assisted in selecting comparison communities on the basis of six criteria:

1. Location/access to markets
2. Population
3. Average household size
4. Availability of services (schools, health clinics)
5. Agronomic characteristics (soil type, temperature, rainfall)
6. Level of wealth

Because of the dearth of recorded data about each community, the extension agents' observations were critically important to selecting comparable comparison communities. A table showing information for program and control communities about each of the six criteria, provided by the extension agents, is shown in Appendix A.

Selection of participant households in program communities

Households were selected to be interviewed in program communities from lists of participants who had already joined a commercial village. Because the commercial villages had just been established and were still small, in most cases, almost all of the participants were interviewed. Twenty-five households were randomly selected from the list of participants, given the inclusion criterion of having a child age 2-5 years. Enumerators located the selected households with the help of extension agents and village/hamlet leaders.

In Arumeru, almost all participating households had declared that they had pre-school age children and were therefore eligible for selection into the study. On arrival to some households, however, it was discovered that there were no children age 2-5 years. The discrepancy is most likely due to the participants' expectation of an extra program benefit for having a pre-school aged child. Because of the small number of total participating households, in order to maintain a sample size of 100 program households in Arumeru, it was necessary to allow some households without children age 2-5 years into the study. In Arumeru, 75% of program households interviewed had children age 2-5 years.

In Kiambu, fewer participating households had young children. In total, 27% of the program households interviewed in Kiambu had children age 2-5 years.

Selection of households in comparison communities

The extension agents and village/hamlet leaders for each community provided census lists of all households in comparison communities with children age 2-5 years. The number of households on each community census list was divided by 20, and the product n was counted from the top of the list so that every nth household was selected. The enumerators located the selected households with the help of extension agents and village/hamlet leaders.

A challenge was that in some cases the lists were incomplete, covering only half of the community; in other cases, the lists were out of date, so that most of the children had grown past the target age range. In these cases, an alternate random sampling method was used:

In the communities where the lists were current but covered only half the geographic region of the community, from the half where a census list was available, half the households (10) were randomly selected. For the remaining households from the other half of the community, the extension agent or village leader made a list of 20-30 households who had a child age 2-5 years, and then the enumerators picked every 2nd or 3rd name on that list to reach 10 names.

In the communities where the lists were out of date, a random selection was made, and households where the child was older than age 5 were still interviewed. Therefore the inclusion criterion of all households having a child age 2-5 years were not strictly followed in either the participant or comparison groups, and only 53% of the final sample in Kenya, and 82% of the final sample in Tanzania had any children age 2-5 years. Given the initial attempt to find only households with children in that age range, the percent of the sample with a child age 2-5 years is probably somewhat higher than the percent of the total population in each study site who had a child age 2-5 years.

Selection of non-participant households in program communities

At follow-up, 15 households in each program community were selected to respond to an abbreviated questionnaire, so that an analysis of program adoption could be done. They were selected from village census lists using the same methodology described above for random selection of non-participants in comparison communities. Households were selected at follow-up rather than baseline to avoid the possibility that a high proportion might join the program in the year between surveys.

Selection of new program participants at follow-up

During the year between surveys, several progam participants at baseline stopped participating in the program, and many new households joined the program. Among those households interviewed as participants at baseline, 61% in Kiambu and 49% in Arusha remained active participants at follow-up. While baseline-only participants were still interviewed at follow-up, their lack of continued participation in the program threatened the validity of the intended analyses comparing non-participants and participants to assess program implementation and impact. Because fewer than half of original participants in Arusha remained active participants at follow-up, the survey aimed to interview an additional 10 new participant households per program village in Arusha only. New participant households were interviewed for two reasons: firstly, to have adequate data to evaluate program implementation among active participants at follow-up, and secondly to provide longitudinal data points on an adequate number of program households for the planned impact survey in 2010. Households with only one data point were used only in the program implementation assessment of this study, and were not used in any impact assessments. New participant households were randomly selected in the same manner as baseline participant households: from program lists of all households who had joined the program since baseline.

Selection of questionnaire respondents

There were three roles in the household that led to respondent selection: (1) the person responsible for the majority of agriculture, (2) the person mostly responsible for TAV production, and (3) the primary person responsible for the care of the child age 2-5 years (or in the case where no child age 2-5 was present, the person responsible for the majority of food preparation).

The household members who filled these roles varied between households, but in most cases, the male head of the household was the person responsible for the majority of agriculture, and the mother of the household was the primary person responsible for the care of the child (or for food preparation). Whether the male or female was primarily responsible for TAV production varied. In no cases were there more than two respondents per household, although in some cases there was one respondent per household, who fulfilled all four roles.

If the needed respondents were temporarily unavailable, the enumerator started with the sections applicable to whichever respondent was available and waited for the other one to become available. If a respondent was out for the day, the enumerators came back the next day to complete the questionnaire. If a respondent was unavailable long-term (such as visiting relatives for a month), the household was not included in the study. The availability of respondents was established at first contact with the household.

Loss to follow-up

In the one-year follow-up survey, five percent of households (20 households) were lost to follow-up. Of the households lost, 10 moved away, three were traveling during the time of the survey, six refused all or large sections of the questionnaire, and in one household a spouse had died and the household no longer farmed. A total of 338 households were interviewed twice, 169 in each site. A total of 142 households were interviewed at follow-up only; 104 non-participants in program communities, and 38 new program participants in Tanzania.

Table 2.3 shows the overall sample sizes attained, showing where households were lost to follow-up and where households were added for adoption and program implementation analyses.

Table 2.3: Overall sample sizes attained

	Kiambu, Kenya		Arusha, Tanzania	
	Baseline	Follow-up	Baseline	Follow-up
Non-participants in comparison villages	81	77	80	76
Participants at baseline	100	31	97	45
Consistently active participants	n/a	61	n/a	48
SUB-TOTAL	181	169	177	169
New participants at follow-up	n/a	n/a	n/a	38
Non-participants in program villages	n/a	49	n/a	55
TOTAL		218		262

2.8.4 Focus group discussions

In each site four focus group discussions (FGDs) were held at baseline, two (one male group and one female group) in an existing commercial village, and two (one male and one female) in a new commercial village. At follow-up, 22 FGDs (7 women-only, 6 men-only, 9 mixed gender) were held before the survey to learn about their experience with program implementation and changes over the previous year; 10 FGDs were held after the survey to share results from the baseline survey and ask for participants' reactions about whether the figures would still be accurate or would have changed. The participants were selected through a voluntary expression of interest to participate. The average number of participants in each FGD was 11. The setting for each was usually in a central community meeting place such as a school, hall, or church, or sometimes in a community leader's home. Each FGD lasted approximately 30-60 minutes. Discussions were simultaneously interpreted between English and Kikuyu/Kiswahili by collaborators who were fluent in both languages and had extensive previous experience conducting FGDs for research. Information discussed was recorded as notes.

2.8.5 Data entry

The research assistants developed a data-entry form and enter the data from the questionnaires using CSPro software [42]. All data were double entered to reduce entry errors in the final dataset.

Focus group notes were reviewed and cleaned/clarified within 24 hours of the FGDs, and were then typed and coded. Notes were subsequently organized in a data spreadsheet (MS Excel) by code topic.

2.9 Methods: Process evaluation

2.9.1 Data sources

Data sources for the process evaluation included the household surveys, focus group discussions, and key informants. Informal interviews with TF program implementation staff were carried out to learn about progam adoption, continuation, and delivery.

2.9.2 Statistical analysis

Statistical analyses were carried out using PASW statistical software (Version 18.0) [247]. Generalized estimating equation (GEE) models were used to predict program adoption and continuation; the use of GEE permitted a logistic regression-like analysis that corrects standard errors for within-cluster correlation of observations [182]. Both generalized and Wald chi-square statistics were used to interpret the analyses.

2.10 Results and Discussion: Process evaluation

2.10.1 Program adoption

Household demographics by program group

Descriptive statistics (Table 2.4) illuminate how comparable the program participants are to non-participants in the same and other villages.

In Arusha, the three groups were generally quite comparable; only participants had significantly more land than both households in comparison villages and non-participants in the same villages. The sample from comparison villages has significantly more preschool children than a random sample of non-participants in participating villages; that is most likely an artifact of the initial inclusion criterion to select only households with children age 2-5 years.

In Kiambu, the participant villages were generally wealthier than the comparison villages, but there was no significant difference in wealth between program participants and non-participants in the same village. Non-participants in program villages had significantly more land and livestock than comparison villages, but program participants were not significantly different from either group. Program

Table 2.4: Baseline demographics

	Comparison	Participants	Non-participants in participating villages
KIAMBU	(n = 77)	(n = 92)	(n = 49)
Years of school (head)	9.0	8.6	8.8
Years of school (mother)*	8.9	8.3	8.1
% female-headed households	13.0	13.0	18.8
Wealth (asset ownership) (geometric mean)	\$820 ^{a}	\$1433 ^{b}	\$1526 ^{b}
Land size (acres)	1.09 ^{a}	2.07 ^{ab}	2.24 ^{b}
Livestock (cattle equivalent units)	1.94 ^{a}	3.02 ^{ab}	4.40 ^{b}
Age of household head (years)	43.06 ^{a}	52.35 ^{b}	58.31 ^{c}
Household size (people)	5.00	4.83	4.57
Nbr. of children under age 5	1.34 ^{a}	0.52 ^{b}	0.31 ^{b}
% U5 children <-2 WAZ	8.0 ^{a} (n=5)	20.8 ^{b} (n=5)	0 (n=0)
Growing TAVs (%)	40.3 ^{a}	88.0 ^{b}	53.1 ^{c}
ARUSHA	(n = 76)	(n = 93)	(n = 55)
Years of school (head)	6.3	6.6	6.3
Years of school (mother)*	6.3	6.8	6.5
% female-headed households	14.7	16.1	23.6
Wealth (asset ownership) (geometric mean)	\$655	\$695	\$947
Land size (acres)	2.33 ^{a}	4.03 ^{b}	2.81 ^{a}
Livestock (cattle equivalent units)	3.91	4.06	3.95
Age of household head (years)	38.70	43.00	39.33
Household size (people)	6.68	6.63	6.07
Nbr. of children under age 5	1.50 ^{a}	1.28 ^{ab}	0.98 ^{b}
% U5 children <-2 WAZ	11.9 (n=8)	12.6 (n=8)	13.5 (n=5)
Growing TAVs (%)	48.7	64.5	51.2

Notes: Equality of proportions was tested using Pearson chi-sq test statistic. Equality of means was tested using a one-way ANOVA. Means with different superscripts are significantly different using Tukey's HSD criterion. Means with no superscript are not significantly different. *The household "mother" (the person who cares for the reference child age 2-5 years or if no reference child, the person who prepares the majority of the household food) is sometimes the same as the head of the household, but usually not.

participants were significantly older than comparison households, but they were significantly *younger* than non-participants in participating communities. Household stucture in program communities may include more elders than in comparison communities, since the average age of household head is greater. As in Arusha, the comparison community had significantly more children than either group in the program community - a result of the initial inclusion criterion. There were also significant differences between groups in the percent growing TAVs. In general, more households in program communities were TAV farmers, and more program participants than non-participants in the same community were TAV farmers.

Prediction of program adoption

A logistic regression analysis was done to understand the factors linked to program adoption. In villages where the program was being implemented, households that decided to join the TF Project are compared to households that did not join. Generalized chi-square statistics for each variable in the model were insignificant ($p>0.05$). While generalized chi-square statistics are generally preferred over Wald statistics when sample sizes are not large [3], Wald chi-square statistics were suggestive of potential relationships between some of the variables in the model and program adoption and are presented in Table 2.5.

In Kiambu, each additional year of age of the HH head was associated with a 4% decreased odds of joining the program ($p=0.001$). Households already growing TAVs were six times more likely to join the program than non-growers ($p=0.040$). Each additional month of food insecurity the household experienced was associated with a 19% increased odds of joining the program. These results echo the demographic characteristics table, as participants were younger and slightly less well-off than non-participants in the same villages.

In Arusha, each additional year of age of the HH head was associated with

Table 2.5: Factors predicting program adoption

	Kiambu		Arusha	
	Odds	p-value	Odds	p-value
Age of household head (years)	0.957	0.001	1.051	0.022
Land access (acres)	1.093	0.153	1.011	0.819
Wealth (log value of assets owned)	0.815	0.378	0.708	0.012
Presence of a child age 2-5 years in the household	0.601	0.285	1.933	0.115
Already growing TAVs	5.894	0.038	1.209	0.749
Months of food insecurity	1.191	0.002	0.932	0.455
Household head gender=male	1.548	0.534	2.119	0.137
Housing quality index	1.073	0.745	1.181	0.357

a 5% increased odds of joining the program. As wealth doubled, odds of joining the program decreased by 29%. Although it appears that the age effect in Arusha contrasts with that in Kiambu, in fact they agree on the age of households most likely to join the program, which seems to be about 43-52. In Arusha, the average age is less than that, and in Kiambu, the average age is greater than that. For wealth, the relationships also agree between countries. Slightly less well-off Kiambu households were more likely to join (more food insecure), as were less well-off households (asset index) in Arusha.

Recruitment: factors likely contributing to joining

In the survey interview, respondents were asked if they had been invited to join the TF Project, and if they were invited but did not join, why they did not. Some of the reasons given included being too busy, having no interest in the project, not liking the appointed commercial village leaders, or lacking water.

Planting TAVs was the defining TF Project output, and it was also the factor most related to program uptake in Kiambu. Data from focus group discussions and survey responses shed light on the major constraints to planting TAVs. Table 2.6 summarizes the results. Sale of TAVs was another main program output; among farmers who grew TAVs but did not sell them, the main reasons for not selling are summarized in Table 2.7.

Table 2.6: Top 5 reasons for not growing, among farmers who did not grow TAVs (several less common responses are not listed)

Kiambu	**Arusha**
(n=57)	(n=72)
Prefer other vegetables (22.8%)	Lack of water (29.2%)
No buyers (17.5%)	Lack of seeds (19.4%)
Lack of land (17.5%)	Prefer other vegetables (18.1%)
Lack of seeds (14.0%)	No buyers (11.1%)
Lack of water (14.0%)	Lack of inputs (unspecified; could include water, seeds, or labor) (8.3%)

Note: percentages may not add up to 100% because households could give more than one response, and not all responses are included here. The percentage indicates the percent of households giving that response, out of all those households who did not grow TAVs.

Table 2.7: Reasons why farmers growing but not selling TAVs did not sell them

Kiambu	**Arusha**
(n=37)	(n=50)
Planted but not yet ready for harvest (48.6%)	Produced enough for home use only (34.0%)
Produced enough for home use only (35.1%)	Other (12.0%)
Lack of buyers (10.8%)	Planted but not yet ready for harvest (8.0%)
Other (10.8%)	Lack of buyers (8.0%)

Note: percentages may not add up to 100% because households could give more than one response, and not all responses are included here. The percentage indicates the percent of households out of all who grew but did not sell who gave the reason noted for not selling.

Lack of water and seeds were among the top reasons TAVs were not grown in both countries. Existing seed systems and seasonality to TAV production are illustrated in the following series of figures.

Figure 2.3 illustrates that Kiambu farmers have many sources of TAV seed including shops, where the majority get their seed by purchasing it. In Arusha in contrast, TAVs are not highly commercialized either as vegetables or seeds; people overwhelmingly obtain seeds from home production and saving, or from neighbors; less than 20% obtain them from traders and shops. The TF project aimed to improve seed supply and quality in both regions.

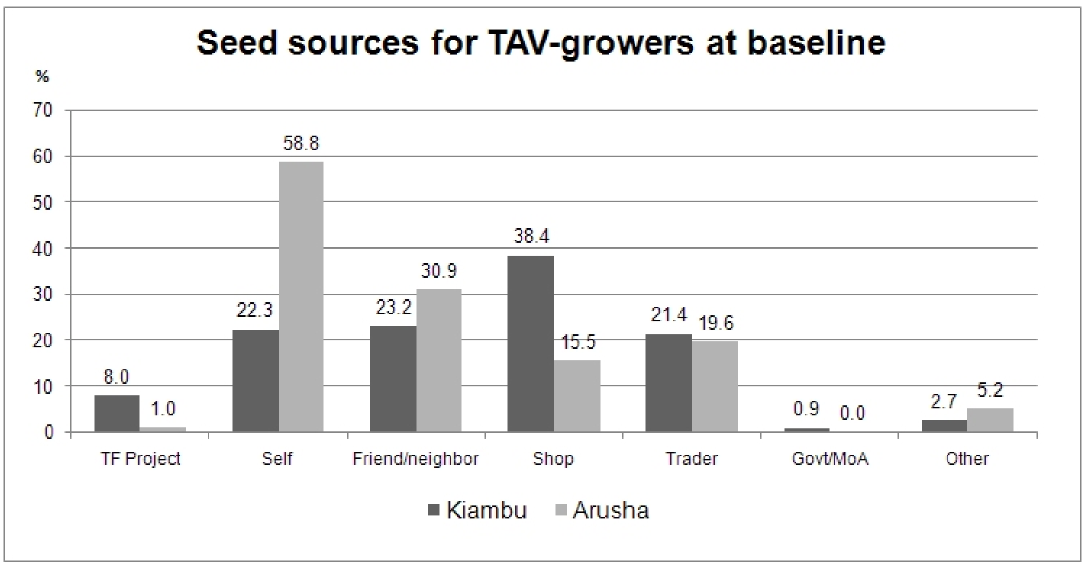


Figure 2.3: Seed Sources for TAV-growers at baseline (% of farmers growing TAVs who reported obtaining seed from each source)

As for lack of water as a reason for not growing TAVs, the hypothesis was that there would be large variations in the population growing TAVs corresponding to the rainy seasons (Figure 2.4). Rainy seasons actually do not seem to be as large of a factor in TAV production as expected. About 50% of those who grow TAVs grow them all year. Among TAV growers who do not grow all year, the Arusha data show a spike during the long-rains season, but otherwise production rates hover between

55-65% of the farmers sampled (Figure 2.6). In Kiambu they are more constant, at about 60% of the sample population (Figure 2.5). About 80% of growers in each site report using irrigation on the TAVs they grow (79.5% in Kiambu, 82.5% in Arusha). From observation, it was clear that mechanical irrigation systems are scarce, particularly in Arusha, so this mostly means watering by hand or ditch. The dry season is very dry, particularly in Arusha. The fact that this crop is able to grow year-round given occasional hand-watering is a testament to it being a fairly drought-resistant vegetable.

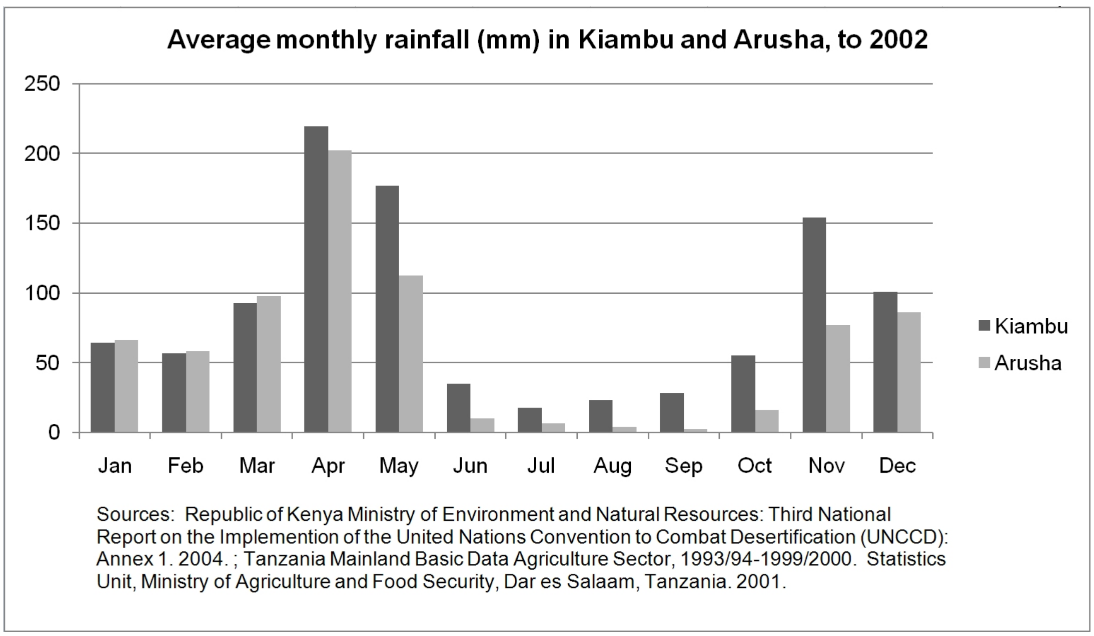


Figure 2.4: Rainfall

Combined, these data seem to indicate that people who have any capacity for even small-scale irrigation can grow TAVs; the lack of large variation may mean that few without irrigation ever sow TAVs at all. Those farmers likely wild-collect TAVs during the rainy season. From figures 2.4 and 2.7, the seasonality of food insecurity in these sites is apparent.[4] Food insecurity in Arusha follows the typical

[4]Food insecurity was measured as the months during which the household had inadequate food in the last 12 months, by respondent report.

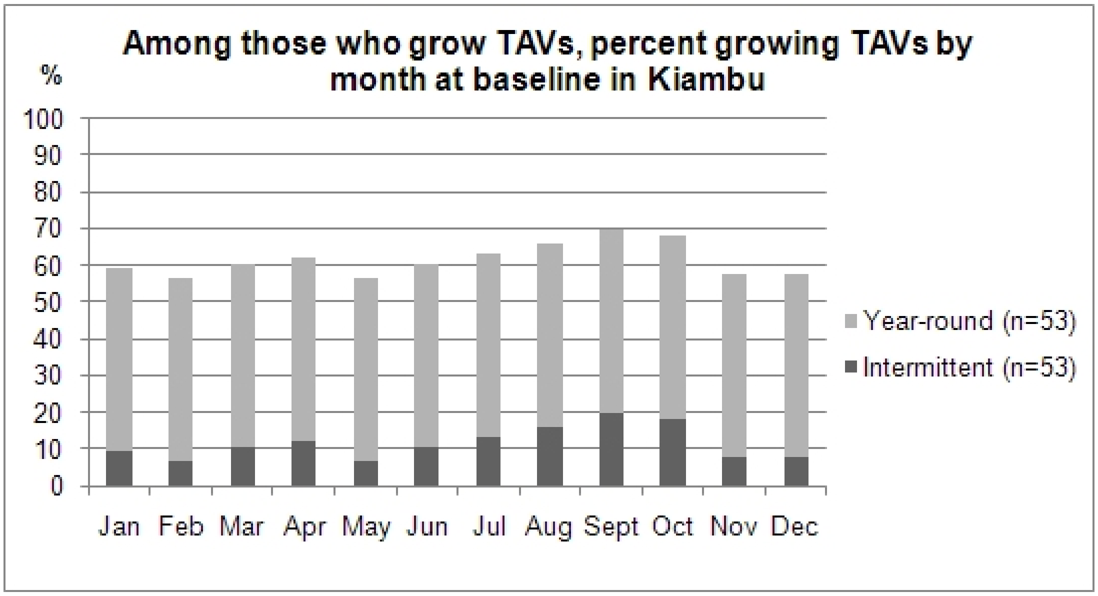


Figure 2.5: Months when TAVs are grown in Kiambu

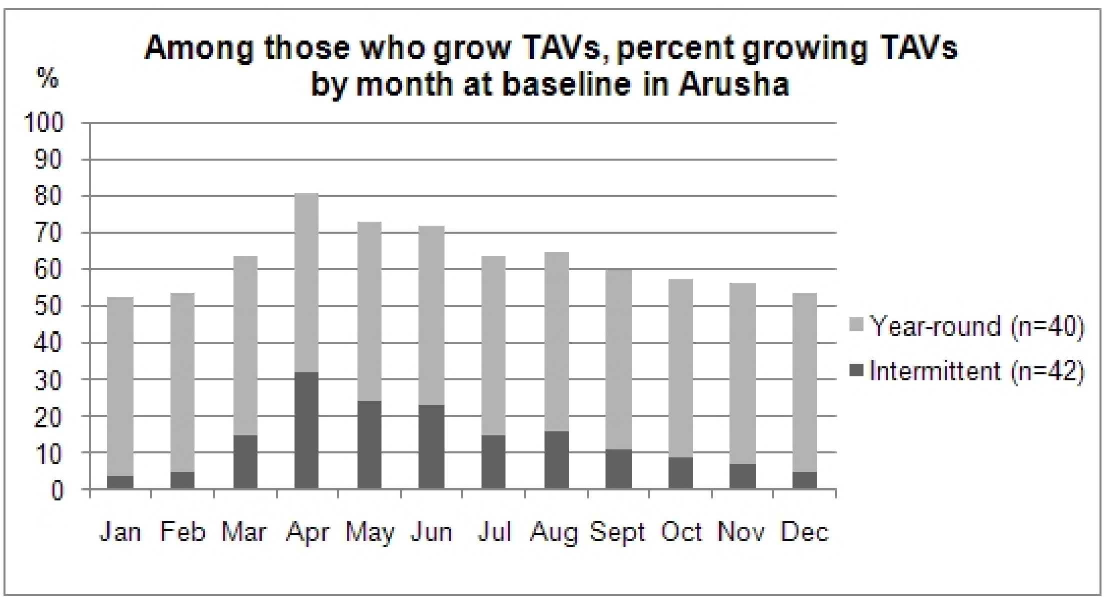


Figure 2.6: Months when TAVs are grown in Arusha

pattern for semi-subsistence farmers, for whom the beginning of the rainy season is the hungriest time, when food stocks are depleted and new crops are planted but not yet ready for harvest. In Kiambu, however, food insecurity appears during the dry season, when food stocks should be high. This is explained by the fact that Kiambu farmers are primarily vegetable-growers, who depend heavily on income

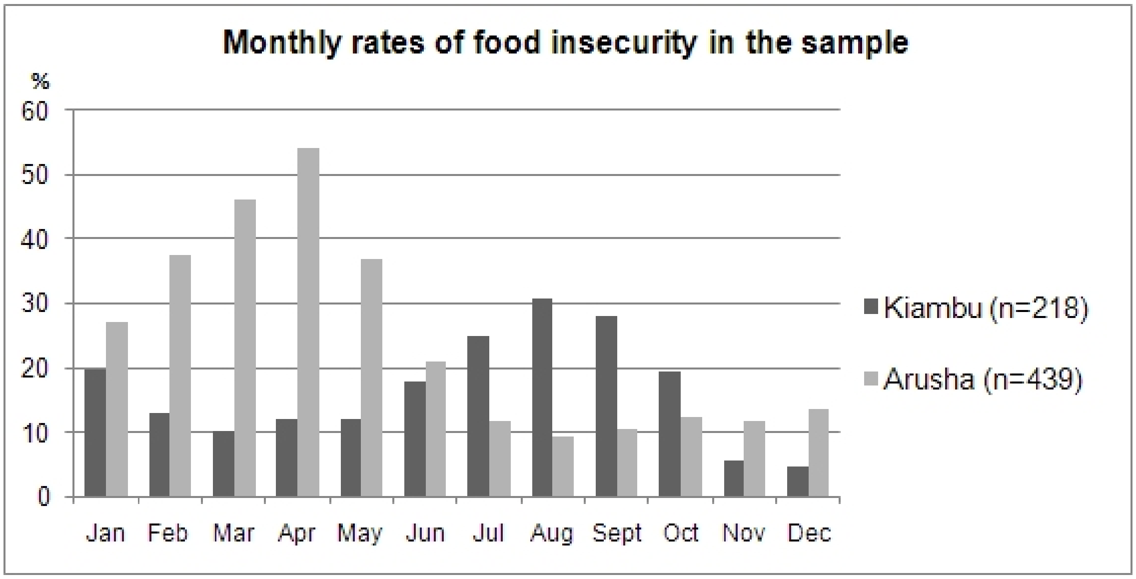


Figure 2.7: Seasons of food insecurity

to purchase other foods. During the dry season, vegetable production is low, and cash flow may be low too. This may further explain why food security was related to program adoption in Kiambu - TAVs grow quickly and could be a source of quick cash for those who are in most need of it from July-October in Kiambu.

The opportunity cost of trade-offs with other crops are also an important factor in whether farmers start growing TAVs. To understand the main crops already grown and the potential trade-offs, Table 2.8 shows the most important crops for sale and for home consumption at baseline, as reported by households in the baseline survey.

In Kiambu, 55% consider kale to be one of their most important crops for home consumption. That could mean that farmers consider green leafy vegetables important to their diet, and that kales (and chard) currently fulfill that role in the diet for the majority of households. TAVs can have a role in diversifying vegetable consumption and on-farm crop diversity. Also it is important that kale, chard, and cabbage are the three most important for sale, even more than tea. These data clearly illustrate that the respondents are vegetable farmers.

Table 2.8: Most important crops for home consumption and sale, 2007

Kiambu		Arusha	
Home consumption	Sale	Home consumption	Sale
Maize (60%)	Kale (53%)	Maize (92%)	Beans (23%)
Kales (55%)	Chard ("spinach") (29%)	Beans (82%)	Maize (22%)
Potatoes (53%)	Cabbage (21%)	Plantains (22%)	Tomatoes (22%)
Beans (46%)	Tea (18%)	Nightshade (7%)	Sweet potatoes (16%)
Chard ("spinach") (29%)	Nightshade (17%)	Amaranth/Sweet potatoes (tie) (6%)	Cassava (15%)

Note: totals may be more than 100% because each household could list the top 3 most important crops for home consumption or sale. Percentages listed are percent of households who named the noted crop as one of the three most important.

In Arusha, nightshade and sweet potatoes are considered to be the most important crops for home consumption after maize, beans and plantains. Clearly, the TF Project could gain an easy foothold among a population that already considers traditional African vegetables to be important crops to their diets. No leafy vegetable ranks among the most important for sale, though; this is the area where TF Project staff most hoped to make inroads in Arusha: to change attitudes and create linkages so that farmers would start to market TAVs, rather than just use them at home.

Farmers in both countries mentioned lack of capital and poor access to credit as a barrier to starting new ventures in general, TAV marketing included. There is generally much higher use of credit in Kiambu. (There are no data on whether this is due to access/availability or to more active seeking in Kiambu relative to Arusha.) In Kiambu, 47.3% of households accessed credit, and of those, 57.5% used the credit for agricultural investment. In Arusha in contrast, 16.6% of the total sample accessed credit, and 28.6% of those households used it for agriculture.

2.10.2 Disadoption vs. Continuation

Among households who signed up for the TF Project in 2007 as participants, 38% dropped out of the TF Project shortly after being recruited. (In Arusha, 50% stopped participating.) According to interviews with program staff, the main reasons households stopped participating were that many expected to get something for free, and left when they did not. Lack of immediate staff presence in Arusha also contributed to initial participants' discontinuation. No regular staff were in place until March 2008, six months after households had expressed interest in participating. Many people reported that they tired of waiting for the program to start. Data on these factors is qualitative; the survey instrument collected data on household-level factors that may have been less apparent to program staff, but which could also have contributed to program disadoption.

A logistic regression suggested household-level factors contributing to the odds of dropping out of the program (Table 2.9). Similar to the above analysis of program adoption, almost all variables were insignificant using generalized chi-square statistics; only the housing quality index was significant in Arusha (p=0.046). Generalized chi-square statistics are typically preferred over Wald chi-square statistics for small samples [3], but here as above, Wald chi-square results are presented in Table 2.9 because they suggest several significant relationships between the predictor variables and program disadoption. While both statistical tests showed results tending in the same direction, the results presented below should be interpreted as suggestive rather than definitive, since they showed significance levels greater than the generalized chi-square statistics.

Using the Wald statistics, in Kiambu, households with a preschool age child

Table 2.9: Factors predicting odds of stopping participation in the program

	Kiambu		Arusha	
	Odds of dropping out of the program	p-value	Odds of dropping out of the program	p-value
Age of household head	1.024	0.112	1.010	0.732
Land access	0.961	0.554	0.806	<0.001
Wealth (LN)	1.241	0.288	0.827	0.368
Presence of a child age 2-5 years in the household	2.995	<0.001	6.673	0.010
Already growing TAVs at baseline	0.272	0.109	2.373	0.050
Months of food insecurity	0.992	0.805	0.673	0.012
Household head gender=male	0.341	0.034	1.802	0.152
Housing quality index	1.268	0.269	4.346	<0.001

Note: statistics presented are Wald chi-square statistics.

were more almost three times as likely to stop participating actively in the program, and female-headed households were three times more likely to stop participating compared to male-headed households. In Arusha, each additional acre of land the household had access to reduced the odds of dropping out of the program by 22%. (Households with more land stayed in the program.) Households with a preschool-aged child were almost seven times more likely to stop participating actively in the program. (Households without young children stayed in the program.) Compared to households who stayed active, households who were already growing TAVs were may have been about twice as likely to drop out, although the result was of borderline significance (p=0.05). Each additional month of food insecurity the household experienced was associated with a 32% reduced odds of dropping out of the program. (The more food insecure households stayed in the program.) As housing quality (an indicator of socioeconomic status) improved one unit,[5] odds of dropping out increased almost 5-fold. (Poorer households stayed in the program.)

If a survey respondent had dropped out of the program, he/she was asked why they stopped participating in the TF Project. Not all respondents answered the qyestion, but responses given included:

- Household planted TAVs but the promised "customers" did not materialize
- Being too old to put in the labor for growing the TAVs (e.g. irrigating) hence not able to continue being a member
- Did not like the idea of selling farm produce as a group; preferred selling as an individual.
- Illness
- There was no benefit or profit in being a member: the varieties advised to grow were not profitable or marketable.
- Participating required too many commitments.
- No time.
- The leaders were not available when needed. *(Unclear whether this means FCI staff or group leaders)*

2.10.3 Program delivery

Program continuation vs. disadoption partly had to do with program delivery. As mentioned, the program in Arusha had a 6-month pause between recruitment of farmers and staff placement, which had a large effect on disadoption. In Kiambu in contrast, the program was rolled out immediately after recruitment.

[5] The units are derived from factor analysis score of floor, roof, and wall materials, and electricity

Survey results

Figure 2.8 shows the percent of households surveyed who received training from FCI. As expected, the comparison households received no training, baseline participants received some, and most active participants received training.

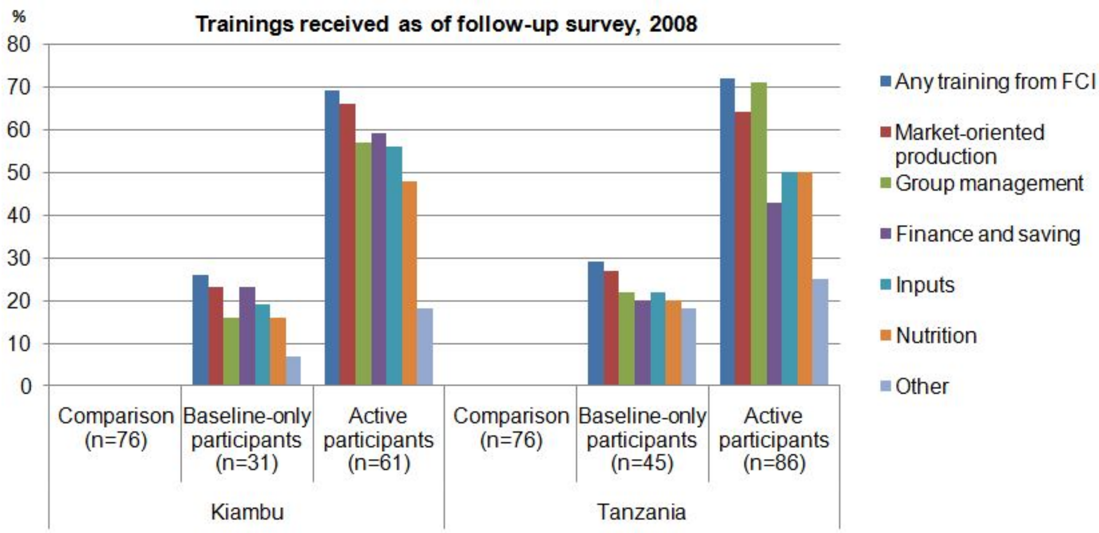


Figure 2.8: Trainings attended

Figure 2.9 illustrates the impact of staff on price information, variety information, seed supply to farmers. This figure shows two things: evidence of staff presence, and plausibility for a possible staff effect on desired program outputs of production and marketing.

Figure 2.10 shows the percent of active participant households adopting desired practices between baseline and follow-up. Practices included growing and selling TAVs at all, and selling TAVs or purchasing inputs as a group. No changes were observed in Kiambu, because rates of desired activities were already so high, probably due to the residual impact of FCI's pilot program in the same villages. Each category except group sales, however, increased significantly ($p<0.05$) in Arusha.

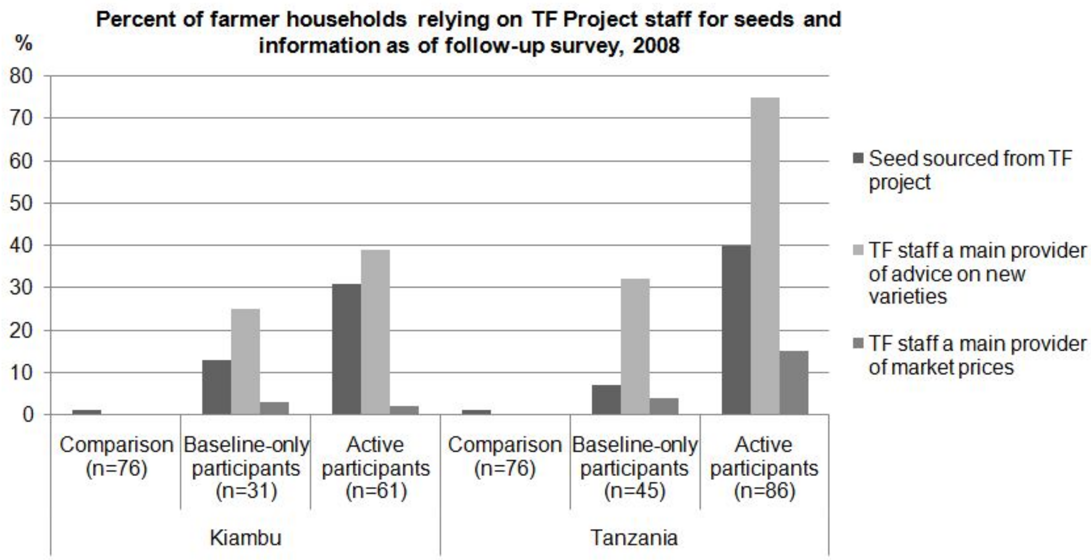


Figure 2.9: TF Project staff impact

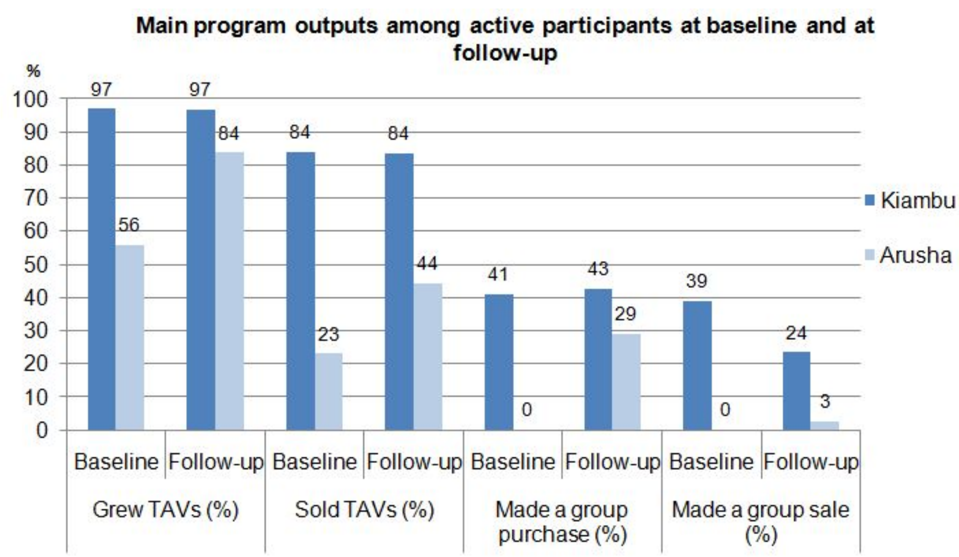


Figure 2.10: Program activity outputs

From pilot project to scale-up: Deja vu or lessons learned?

As stated, the TF Project was a scale-up of a pilot project, which was highly successful in Kiambu, and all but forgotten in Arusha. Many of the factors that contributed to the success of the pilot project (2003-2006) in Kiambu and its failure in Tanzania remained the same and are relevant here, including external barriers and facilitators to success.

Barriers and facilitators

The first set of factors that facilitated program success in Kiambu compared to Arusha had to do with context in each place. Kiambu is next to Nairobi, which has a population of approximately 6 million. Many supermarkets have opened in Nairobi in recent years, several of which the project was able to work with to market traditional foods to consumers. That was not an easy or an automatic feat - it still required substantial effort for the program to successfully connect small farmer groups to supermarket chains, and to convince the supermarket management to try the project. Yet Nairobi provided ample opportunity to try such a project, while Arusha did not offer as many opportunities. Arusha has a population of 200,000 - 30 times smaller than Nairobi - many of whom are expatriate Europeans and North Americans. From the start it might have been possible, but involving perhaps more and different challenges, to market "heritage" foods to a foreign clientele, who had no memories of eating such vegetables as children and therefore little or no familiarity with the somewhat bitter leaves. Further complicating the situation was that during the pilot project and scale-up, there was only one supermarket in Arusha, part of a South African-owned chain that had a general policy of importing its produce from South Africa. The supermarket management was not very receptive to marketing TAVs, particularly given their expatriate clientele, added to the fact that they had had unfavorable experiences in the past trying to partner with local farmers for fresh produce supply [237]. Finally, the supermarket was located right across the street from a multi-acre outdoor market which operated every day. Tanzanian and foreign residents alike did most of their produce shopping at the open air market, or at other smaller outdoor markets found throughout the city. Therefore, unlike the supermarkets in Nairobi, the supermarket in Arusha was not an optimal base for TAV promotion.

Another advantage Nairobi had over Arusha in facilitating project success was a small but committed base of city residents who sought to buy TAVs, even while many urban consumers needed to be convinced to try them. In Nairobi, it is not easy to grow a home garden, and many people who moved to the city from Western Kenya and other provinces where TAVs are still commonly used may have craved the taste of TAVs that they grew up eating. These people would have been the first to buy TAVs once they were offered in supermarkets and other Nairobi markets. In Arusha, in contrast, it appeared that many Tanzanian residents who would have desired TAVs had the ability to grow or collect them for themselves, in small garden plots or larger farms they owned away from their city home. In focus group discussions for this study, Arusha farmers sometimes noted that a limitation to TAV sales was that anyone could go and pick TAVs from the wild for themselves. (This was not necessarily true if a consumer desired a specific variety and volume, but in general it was easier for people to produce TAVs for themselves in Arusha than in Nairobi.) TAVs were sold in all the large outdoor markets in Arusha, but large increases in demand looked more uncertain there than for Nairobi - unless the expatriate and tourist market could be tapped.

A very important facilitating factor was that this project rode on the momentum of a decades-long history of TAV promotion in Kenya.[6] Efforts to revitalize TAV production and consumption in Kenya started in the 1970s. At first confined to small regional projects and university studies, more partners and grants to promote TAVs started building through the 1990s. By 2001, a multi-organization meeting and loose consortium of universities, local NGOs, international agricultural research organizations (CGIAR and AVRDC), and government institutions

[6]All information on the history of TAV promotion was obtained from an interview with Dr. Patrick Maundu, a researcher at Bioversity International and the Kenya National Museums, who has personally been involved in TAV promotion activities in Kenya since 1985.

(Kenya National Museums and Kenya Agricultural Research Institute) began intensified promotional efforts. These included an annual government-supported TAV promotion festival, including a parade, banners, a TAV cooking competition, and a traditional dance festival. FCI, though it had an important and successful role in connecting smallholder farmers to markets in Nairobi in its pilot program from 2003-2006, was only one of 12 NGOs supported in TAV-promotion projects throughout the country at the same time, and was clearly supported by the facilitating environment of multiple other TAV promotional activities going on simultaneously with their own promotions.

At a national policy level, TAVs are also gaining some traction in Kenya. The Kenyan government now serves TAVs in their cafeterias,[7] and is drafting an updated National Food and Nutrition Policy with specific reference to TAVs, in particular the policy of including TAVs in training materials for agricultural and health extension agents.[8]

Contrast that environment to Tanzania, where to date there have been no coordinated efforts to promote TAVs, and no mention of TAVs in any government policy. Since the 1990s, AVRDC has been the only organization to provide technical expertise, seeds, and training in agronomic and cooking techniques for TAVs, as well as nutritional analysis and information consistently. They have partnered on a limited scale with Bioversity International (a CGIAR agency), but the main Bioversity offices are in Nairobi, where that organization's promotions of TAVs have been focused. Some researchers at Sokoine University (the main agricultural university in Tanzania) and European and North American universities have studied TAVs in Tanzania, but not on a coordinated basis. While AVRDC has

[7]Personal communication: interview with Eunice Motemi, affiliated with Kenyatta National Hospital and the Kenya Ministry of Health, August 26, 2008.

[8]Personal communication: interview with Tumwet, Kenya Ministry of Agriculture, August 26, 2008.

carried the torch for TAVs in Tanzania, they have not benefited from extensive partnerships such as those in Kenya. Furthermore their reach is mostly within the Arusha region, where farmers can attend trainings at the Center and staff and affiliated researchers can more easily travel to nearby farms. At the 2007 annual national agricultural exposition, AVRDC appeared to be the only booth in the fair to include any seeds or information about TAVs.[9] This was in stark contrast to Kenya's proposed national-level policy changes and annual government-sponsored festival for TAV promotion, in collaboration with international institutions and civil society activities.

Implementation

In addition to the divergent contexts in which the pilot project took place, FCI's program implementation (2003-2006) was also very different between Kiambu and Arusha.[10] During the **pilot project**, FCI did not have an office in Arusha; staff based in Nairobi periodically traveled across the border to Arusha to visit farmer groups (a six-hour trip on rough roads). Initially, FCI staff spent some time in Arusha, promoting the project, inviting farmers to join, and forming farmer groups among those who expressed interest. FCI also partnered with local extension agents employed by the Tanzania Ministry of Agriculture, as a strategy so that the extension agents could keep in regular contact with farmer grops to sustain the program momentum [237]. While partnership with extension agents was politically necessary and may have seemed like a good idea practically as well, it turned out the extension agents varied greatly in their contact with farmers as well as in their commitment to any program ideas. During post-pilot follow-up interviews in 2007, one group reported that they had not seen their extension agent in over a

[9] Personal observation.

[10] Tara Simpson's Cornell University M.P.S. thesis [237] explored in depth why the FCI pilot project failed in Arusha.

year, although the agent in question was still employed and assigned to their village [237]. Not all extension agents were absent, but even those most engaged could not effectively sustain the FCI pilot project, because they had limited understanding of what exactly, operationally, the project was trying to do, and could not be responsible for any specific program activities other than mere contact with the groups that had been formed. FCI staff, increasingly busy with the Kenya side of the project, visited Arusha infrequently and most farmers who had been initially involved reported that the project had been "abandoned" shortly after the groups were formed [237]. While they had not made any major investment in the project, several farmers reported dissatisfaction with what they felt was raising of false expectations at the start of the project [237].

In contrast, FCI staff were in weekly contact with groups in Kiambu, and between visits to farmer groups, were busy working with supermarkets, traders, and other brokers to set up links between the new farmer groups and opportunities for sale and transport. Kiambu groups received frequent trainings on group leadership, management, and market-oriented production, none of which the Arusha groups received. Midway into the pilot project, as noted above, the farmer groups had successfully initiated contracts with major Nairobi supermarkets.

The TF Project took several steps to correct these problems in the scale-up. Firstly, they hired two full-time staff to be stationed in Arusha, where they shared an office with AVRDC. Collaboration with AVRDC was the best possible partnership, given AVRDC's history of working with TAVs in Arusha. This collaboration and office placement allowed FCI to depend far less on extension agents than during the pilot project - which was clearly a strategy that had not worked well. Being placed in Arusha allowed the FCI staff to have frequent contact (usually weekly meetings) with the farmer groups, much as was being done in Kiambu. Transportation, however, was inherently more difficult in Arusha as some groups were very far from the offices on rough, dusty roads, and the transportation budget was inadequate to cover FCI staff's costs. In the scale-up, location of staff did not limit farmer visits, but transportation still did. Staff visited the distant groups less frequently.

Another improvement made in the TF project over the pilot project was an unplanned and opportunistic collaboration with another NGO in Arusha, AAIDRO (Archdiocese and International Development Relief Office). AAIDRO was starting a program on market access for farmers at the same time as the TF Project was starting, and although the program theories were quite different, the similar program aims caused FCI and AAIDRO staff to decide to work together in villages, each implementing complementary program activities. FCI staff noted that the AAIDRO activity of group savings and small cash loans was a major motivator for farmers to attend meetings, which helped FCI staff to reach the farmer groups without having to provide 100% of the motivation to meet.

In both project phases, understanding of program theory among individual FCI staff was remarkably cohesive. In 2008 interviews with each staff member involved in both the pilot project and the TF Project, each staff member reported an identical chain of activities and events that would lead to the desired program outcomes. Therefore confusion over program activities or messages was definitely not a limiting factor for program success in either country. The only difference in program implementation between the countries was what was actually implemented: how often the groups were reached, how much support they had, and whether market linkages were aggressively pursued. In Arusha, the group support and market linkages were overall much less what was being done in Kiambu.

A limitation that the TF Project did not address was that of weaker marketing possibilities for TAVs in Arusha through the planned venues. Supermarkets did not seem to offer many possibilities in Arusha for the reasons mentioned. Due to the high tourist and expatriate population in Arusha, a different marketing stategy was needed to reach new markets, compared to the strategy used in Nairobi which targeted wealthy Kenyan consumers. The scaled-up program failed to sufficiently explore and exploit innovative other marketing channels. The tourist population offered a virtually untouched niche market for TAVs, as many backpackers sought "African" food for their short stays near Mt. Kilimanjaro, but only found standard continental fare at hotels and restaurants. Interviews with several hotel chefs in Arusha revealed that the chefs were quite interested and willing to experiment with using TAVs in their recipes. While this information was offered to TF staff, they felt that they lacked the capacity to make many changes to their strategy once the program had been planned and begun, and the strategy that had worked well in Kenya was not substantially changed for Arusha.

The underlying problem behind the lopsided implementation of the pilot project in both phases was lack of funds. With limited funds, FCI made the strategic choice to use funds and staff time in the location where success was most probable. Given the background circumstances described above, there was no question that the most promising site was Kiambu. FCI's success with their Kiambu farmer groups, and their international recognition for that success, allowed them to receive a grant to scale up the project in Kiambu and three other locations, including Arusha. An unfortunate reality of fund-raising is the unintended consequence that in order to show impact, programs will gravitate toward easy targets and shy away from those most in need; in this case, the Arusha farmers had the weakest hope of market linkages, and were therefore the hardest to help.

2.11 Expectations for impact

Attitudes among farmers are very likely to have shifted in a positive direction. Program staff had frequent contact with groups in both places, and FCI staff were skilled promoters of TAVs using many angles. (They are primarily a marketing agency.) TAV promotion was present throughout all activities in varying levels of subtlety. It is very likely that attitudes would shift due to the program.

Knowledge about nutritional value of TAVs is somewhat likely to change among farmers, though the exact messages are likely to be unclear and possibly incorrect. Only about 50% of active participant farmers attended any nutrition training. Consistent nutrition messages were not given, although overall it was clear that TAVs were being promoted based on health-promoting attributes.

Production may have increased, mostly due to the initiation of demonstration plots, seed provision, and agronomic information from staff. In FGDs participants insisted that they were increasing production of TAVs. It is expected that production did increase moderately, especially in Arusha where fewer program participants started off as major TAV producers already.

Marketing probably did not increase in either site. Sufficient resources to market TAVs were not provided in Tanzania, although the idea/plan was discussed. Any changes in marketing in Tanzania would likely be due to farmers acting on advice and empowerment, or greater sales purely from increased production, rather than from direct program assistance in accessing markets. Tanzanian farmers said in focus groups that they were ready and motivated to sell TAVs; they just needed markets, which had not materialized. In Kenya, 2008 was a particularly bad year for marketing for several reasons, notably the election turmoil and the price spike for transport and inputs, affecting production and ability to take produce to market. These factors probably affected any potential sales gains for everyone; the program probably did not impart any tools to overcome high prices and blocked roads, even for participants. Farmers said in focus groups that sometimes they could not afford to transport their TAVs to the same markets as before, and shifted their sales elsewhere. The program carries low expectations for marketing impact in both countries.

CHAPTER 3

REVITALIZING UNDERUTILIZED CROPS: THE ROLES OF PRODUCTION, MARKETING, KNOWLEDGE AND ATTITUDES IN TRADITIONAL VEGETABLE CONSUMPTION AMONG SMALLHOLDER FARMERS IN KENYA AND TANZANIA

3.1 Introduction

The aim of this paper is to test whether an intervention aimed at increasing production, marketing, and consumption of traditional African vegetables (TAVs) affected TAV consumption among participants small farmer households and, if so, how.

3.1.1 Nutritional context

Nutrition in sub-Saharan Africa is primarily characterized by high rates of child undernutrition. In Kenya, child stunting and underweight have been constant at 35% and 21%, respectively, since 1990 [270]. In Tanzania, stunting rates have declined slowly to a current rate of 38%, and underweight has declined to 22%, although rates are dropping too slowly to meet the Millennium Development Goal of halving 1990 rates by 2015 [270]. Micronutrient deficiencies are also widespread [271].

Alongside persistent undernutrition, there is evidence of a nutrition transition occurring particularly in and near urban areas. As seen in many developing countries, diets shift to increased consumption of sugar, fat, refined carbohydrates and processed foods, increasing prevalence of overweight, obesity and related chronic disease [58, 204, 206]. Overweight exceeds underweight among women in both urban and rural areas of both countries [168], and although data are scarce, local accounts are of rapid increases [141, 23]. Within the next 20 years, close to a three-fold increase in diabetes and heart disease over 2000 rates is predicted in sub-Saharan Africa [296].

These nutritional problems are occurring in a context where the majority of households are smallholder farmers. Both kinds of malnutrition - undernutrition and overnutrition - are linked to poor dietary quality. Agricultural and food system-based solutions can be a direct means of addressing malnutrition.

3.1.2 Potential for traditional foods to improve nutrition

A number of studies detail how wild foods or neglected crops can contribute greatly to the nutrient adequacy of rural diets [184, 89, 223, 45, 144]. Wild edible plants have been found to contribute high amounts of micronutrients to indigenous people's diets in several sub-Saharan countries (Burkina Faso, The Gambia, Mali, Niger, Swaziland, and Tanzania) [89]. Promoting local foods also may curb the nutrition transition. Retention of traditional foods, through agricultural policies as well as strong sociocultural beliefs and food traditions, is attributed to ushering South Korea through 40 years of rapid economic development unscathed by the usual nutrition transition effects of economic growth, with cardiovascular disease rates 1/16th that of the United States [140]. Similarly, the traditional Mediterranean diet is linked to the sustained health of Mediterranean populations, and is indeed the inspiration for much of the epidemiological research relating food variety, resveratrol, lycopene, and unsaturated fats to human health [123]. Promotion of TAVs in East Africa may be one way to reduce the transition to a Westernized diet and poor health. The decline in traditional diets in Tanzania has been cited as a cause of the currently accelerating nutrition transition [211, 160].

That traditional foods are valuable in the diets of the indigenous and the poor, however, is part of the reason that they are lost as populations have access to modern or western foods associated with the rich. Since colonization in Africa, traditional foods and wild vegetables have been stigmatized. The General Manager of the British Central Africa Company observed in the early 1900s, "We are definitely of the opinion that if the natives of this country are left to their own devices they will *starve themselves* in a very few years" (emphasis in original) [130]. Stigma based on modernization picked up where colonization left off. A Kenyan scientist describes his experience at school lunch time in the 1960's: "If your mother cooked cabbage (which was grown in urban areas at that time), you talked about it to the other boys and it was a big delight when your turn came to share your food. If you brought traditional vegetables, you hid yourself over lunch hour to eat alone" [212]. The process by which traditional and wild foods are stigmatized and displaced by acculturated preference for modern or nonnative foods has been called "gustatory subversion" [152]. Gustatory subversion can result in permanent losses of knowledge that would be helpful for public health nutrition. Johnson and Grivetti (2002) invoke the term "nutritional extinction" to describe the phenomenon of poor diets in the midst of plenty: "Certain edible wild plants could be ecologically stable and present throughout a given geographical area - but in actuality be *nutritionally extinct* - because such plants no longer are recognized by family members and no longer contribute to household food intake" [124]. Attitudes and knowledge about traditional and wild foods are as important as their availability.

Agricultural extension and nutrition education projects have a large role in ensuring that they are not the cause of gustatory subversion or nutritional extinction, either by design (intentional displacement or disparaging of traditional foods) or by ignorance [81]. Development programs need not be the culprit of unintended negative consequences for food security and nutrition. Efforts to understand and incorporate traditional foods and food-production strategies into agricultural programs can avoid permanent losses of knowledge and use of nutritionally important food resources.

This research is based on the available evidence that traditional African vegetables are important to nutrition and food security. The context of the nutrition transition in Kenya and Tanzanian urban centers presents an extraordinary opportunity for small farmers to profit while benefiting the health of the upper class. Lang notes, "the coincidence of over- [and under-consumption] within societies is likely to remain and possibly grow...agriculture will face renewed pressure to deliver, via sustainable methods, not just more food, but better-quality and health-enhancing foods" [148]. Traditional African vegetables have been stigmatized and their use has declined over the past 100 years, but recent efforts, including the one described in this paper, have begun to recognize their cultural, nutritional, and ecological importance and to revitalize their use in East Africa.

3.1.3 Intervention description

The Traditional Foods Project was designed and implemented as an income-generating program within the context of the dual burden of malnutrition, and aimed to capitalize on the many attributes of underutilized traditional foods that could potentially make inroads into poverty and malnutrition. The goal of the program was to increase production and marketing of traditional African vegetables (TAVs) among small farmers, and to improve household income and nutrition. It was a three-year program implemented in Kiambu, Kenya and Arusha, Tanzania by the International Potato Center (CIP), the World Vegetable Center Regional Center for Africa (AVRDC-RCA), and Farm Concern International, a Kenyan non-profit organization.

The program had four main components: (1) agronomic training and seed supply; (2) farmer cooperative formation and links to buyers; (3) a nutrition-focused marketing campaign, which used posters, flyers, demonstrations, and television to promote the image of TAVs among consumers, based on their nutritional content; and (4) farmer training about the nutritional content of the vegetables.

There are hundreds of traditional African vegetables [32], but five were chosen for promotion in the TF Project based on their nutritional profile, their existing abundance in the sites' agroecosystems, and their popularity relative to other TAVs, which gave them a higher potential for marketability. All five of the TAVs were dark green leafy vegetables: amaranth (*Amaranthus* spp.), nightshade (*Solanum nigrum, S. scabrum, S. americanum*), African spider plant (*Cleome gynandra*), sweet potato leaves (*Ipomoea batatas*), and cowpea leaves (*Vigna unguiculata*).

TAVs have several attributes which make them an ideal crop for promotion in this context:

- Nutrient content: They are rich in micronutrients, particularly iron and provitamin A. (See Chapter 2 for nutrient content table.)
- Income Generator: They can be a fast income generator because they grow rapidly, in 4-6 weeks, and can be harvested multiple times per planting
- Low maintenance: In general they require fewer inputs than exotic varieties, since they are well-adapted to the agroecosystem; amaranth, nightshade, and spiderplant commonly grow as weeds, even in dry seasons. They compete well with weeds.
- Women's crops: women may have a chance to control income from them if they are sold.

- Contribution to a healthy food system: Vegetable production is generally too low for population needs in sub-Saharan Africa [75]. By growing TAVs and marketing them to consumers, farmers are leveraging biological diversity and cultural traditions to increase healthy food offerings in both rural households and urban centers.
- They maintain ecosystem services: Farmers use TAVs to regenerate soils and sometimes as pest biocontrol; planting TAVs also can increase on-farm biodiversity.

3.1.4 Hypothesized factors facilitating consumption of promoted foods

Supporting the aims of this paper is to understand whether or not farmers accept and use TAVs. Whether interventions ultimately succeed or fail at promoting production and consumption of certain foods among small farmers has to do with myriad context-specific factors but also some generally accepted pathways from agriculture to nutrition.

When specific crops are promoted for consumption, the first question is whether the farmers actually produced the target crop. There may be substantial resistance to growing crops for which there is no viable market, since at the peak of harvest there is usually a surplus of the crop, more than can be used by the household. If farmers have no way to sell the surplus, they may likely choose other, more marketable crops. An example of this effect was observed in Bangladesh, where rural farmers preferred growing rice, which they could store, to fresh vegetables, until a bridge was built which enabled them to access the Dhaka market to sell their vegetables [175]. In addition to physical barriers to markets, there may also be barriers to selling unfamiliar crops, which consumers are not accustomed to purchasing.

Aside from consumer preferences, smallholder farm households may also balk at growing new crops if they themselves do not prefer to consume them - if they are unfamiliar, distasteful, or socially undesirable foods. People's **attitudes** about the acceptability and social desirability of eating certain foods can have a strong influence on when, where, how often, and by whom they are eaten [164, 243, 229]. The food industry understands this concept intimately, knowing that increasing the awareness and social desirability of food through advertising directly raises consumption (and revenues). In an agricultural setting, people's attitudes about foods also may influence whether those foods are planted, thereby influencing their availability to farmers. Outside of the private sector, studies have shown social marketing to increase consumption of target foods [43, 156, 143, 240]. In the consumer behavior literature in developed countries, attitudes have been used to predict food purchase and use [230].

In a pilot project before the program under study, TAVs were perceived as nutritious, but they also were perceived as "a poor person's food" and, as such, carried a negative stigma that could limit their cultural acceptability [63]. Weinberger and Swai studied attitudes toward TAVs in a household survey in Tanzania, although their analysis was desciptive and did not link attitudes to consumption at the household level [289]. An educational program for children, which aimed to create awareness of cultural identity and teach children to identify wild food plants, resulted in higher plant recognition among the children, and educators believed that the children had more positive attitudes about wild food plants after the program (although no attitudes were actually measured) [41]. This study builds on previous literature by measuring attitudes as they relate to consumption.

Even if farmers grow a new crop, they may not consume what they grow for other economic reasons. If farmers can obtain high prices for their produce, they may be more likely to save less of it for home use, opting instead to earn the high prices and buy cheaper foods. Decisions about use of crops for sale or home consumption have to do with intra-household power structures and household decision-making. Part of intra-household decision making about food has to do with knowledge about the nutritional value of the food. Interventions at the nexus of agriculture and nutrition have shown that nutrition education may be a critical component of interventions aiming to increase home consumption of certain nutrient-rich crops, such as dark green leafy vegetables and orange-fleshed sweet potatoes [95]. If family members, particularly the women who prepare food for the household, understand the health benefits of a food, they may be more likely to seek and serve it for the health of their family. This may override decisions based solely on market price - nutritional qualities can add value to the monetary value of food.

Knowledge about health benefits of a food is not limited to biochemical nutritional content. In some cases, particularly where a plant is indigenous or has adapted to the region over many hundreds of years, local knowledge is present about its medicinal value. In Arusha, Tanzania, most farmers are of the Wa Arusha tribe, who are sedentary Maasai; many have settled within their own or one previous generation. The Maasai use a wide variety of herbs, shrubs and trees medicinally [116], knowledge which would likely be present to some extent among the Wa Arusha as well. Previous studies have reported the medicinal use of traditional vegetables in the Arusha region, and also in the Nairobi region of Kenya [32, 131]. Health "value" of foods, particularly traditional vegetables, may therefore encompass more than a western-oriented nutritional content; people may also be more likely to grow and use these crops if they have knowledge of the crops' medicinal value. Medicinal knowledge also might play a role in households' propensity to grow and consume vegetables.

In all, the following factors are hypothesized to affect the success of an intervention in increasing production and consumption of a specific crop: production, marketability, perceived value (including but not limited to farmgate prices), attitudes, and knowledge about health benefits of the food, including nutrition knowledge, and indigenous knowledge about medicinal uses.

3.1.5 Traditional Foods Project program theory

One aim of the TF Project is to promote farmer household consumption of TAVs. The project planners and implementers described three main pathways for increasing TAV consumption, corresponding to program activities (shown in Figure 3.1). The overall context was of increasing marketability so that farmers would grow the vegetables. Household price effects and medicinal knowledge were not part of the program theory. The following conceptual framework illustrates the hypothesized pathways from the TF Project outputs to increased TAV consumption.

3.1.6 Objectives

This study aims:

1. To show whether the **program** was related to the outcome of increased traditional African vegetable (TAV) consumption, and
2. To test the program theory that
   (a) increased TAV **production**,

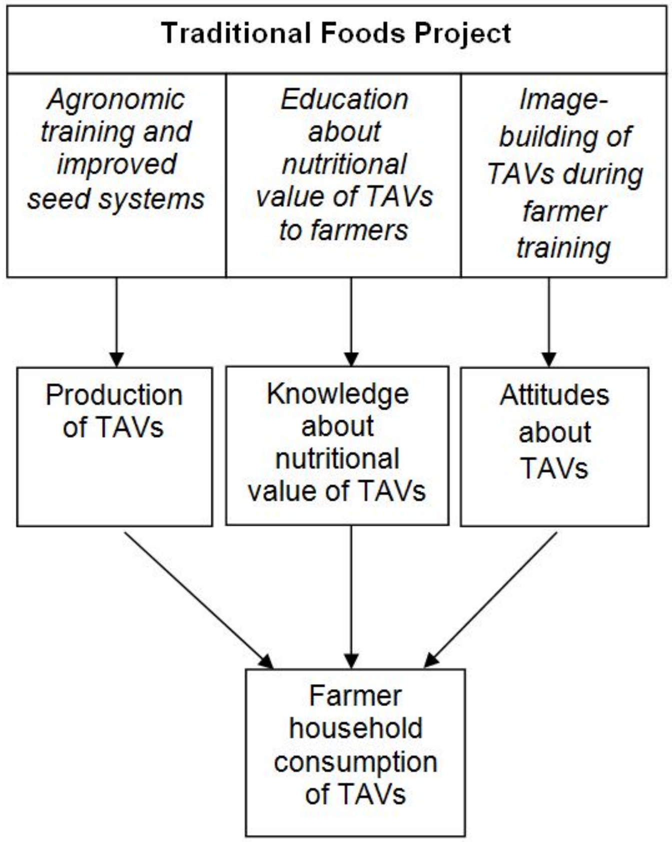


Figure 3.1: Conceptual Framework illustrating the TF Project planners' program theory

(b) increased **knowledge** about health benefits of TAVs, and

(c) more favorable **attitudes** to TAVs based on a nutrition-focused marketing campaign

would lead to increased consumption of TAVs.

3. To examine other hypothesized factors for consumption, particularly medicinal knowledge of TAVs.

3.2 Methods

3.2.1 Study design and survey

A pre-post intervention design with a comparison group was used to test how program participation and program theory were related to TAV consumption. A baseline survey was carried out in each site immediately following recruitment of households into the program, and a follow-up survey was administered to the same households one year after baseline. The survey was administered to 358 farmer households at baseline (October, 2007); 181 households in Kiambu, Kenya, and 177 households in Arusha, Tanzania. In the one-year follow-up survey, five percent of households were lost to follow-up, mostly due to moving away. A total of 338 households were interviewed twice, 169 in each site.

Sampling frame

In each country, four districts were included in the study. Prior to the start of the study, program staff had selected four villages for the TAV program implementation, which were located in four different districts. Program staff reported that the main selection criteria for villages where the program would operate were prior experience producing horticultural crops, agronomic suitability for production, and proximity or access to markets. In keeping with the overall evaluation design, in each district, another village was selected based on similarity to the program village in size, wealth, proximity to markets, average household size, and public services availability. The survey was therefore administered in eight villages: four program villages, and four matched comparison villages. In each program community, 25 households were interviewed, and in each comparison community, 20 were interviewed. Households were located again at follow-up using maps created from

GPS locations taken at each household at baseline. All households were found, but 5% of respondents in each country were lost to follow-up due to moving, being away, or refusing to answer all or parts of the questionnaire.

Respondent selection

In program villages, households to be interviewed were selected randomly from lists of program participants. In comparison villages, households were randomly selected from village census lists. The initial intent was to interview only households with children age 2-5 years, but this inclusion criterion was subsequently dropped because many households who were recorded as having young children actually did not have children in that age group. Respondents within the household included three distinct roles: the person mainly responsible for agriculture, the person mainly responsible for TAV production, and the person mainly responsible for taking care of the reference child age 2-5 years (or if there was no child, the person responsible for the majority of the cooking for the household). If a required respondent for a particular questionnaire section was temporarily unavailable, the interviewer made an appointment to return later in the day or week to complete the questionnaire with the appropriate respondent.

Household survey administration

The survey was administered over a period of four to five weeks simultaneously in both sites, to ensure comparable seasonality. The follow-up survey was administered exactly one year after the baseline also so that changes seen in agricultural production and TAV use were not due to differences in seasonality. Teams of interviewers administered the questionnaire in the local language of respondents, which was Kikuyu in Kenya, and Kiswahili or Maasai in Tanzania. During interviewer training, the importance of communicating consistent meaning of each question was emphasized, and role playing, discussion, and practice interviewing ensured that interviewers fully understood each question and agreed on its exact translation. The survey took one to two hours to complete for each household. Each day of the survey, research assistants and the PI reviewed the filled questionnaires, held a de-briefing session with enumerators, and returned any questionnaires with inadvertently missing information for follow-up.

Data entry and cleaning

Data were double-entered in CSPro data entry software [42], using electronic forms that looked identical to the printed survey questionnaire. Frequencies, histograms, and cross-tabulations were used to detect outliers, and implausible data were recoded or removed. In some cases missing data could be found during the data cleaning process; for example if the number of TAVs grown was missing, but in the list of crops grown for the same household, TAVs were listed individually as having been grown. Wealth data presented a particular challenge in identifying true outliers. Households with a change in wealth greater than +/-2.5 standard deviations from the mean appeared to be outliers from the rest of the observations. Such large changes in wealth were highly unusual, but possible, for example if a car or motorcycles were purchased or sold during the year. Each observation of a wealth change greater than +/-2.5 standard deviations was examined for plausibility and consistency with other household indicators of wealth, including housing quality, household food security, and reported overall change in economic situation and the reasons for the change. Some of the outlier households reported an implausible durable goods change, such as the purchase of 4 tractors (where no other farmer in the survey had any tractor). All such implausible cases (4 in Kiambu, 8 in Arusha) were excluded from the analysis, assuming errors in asset index data collection or entry. The remaining plausible large changes in wealth had to do with the sale or purchase of a motor vehicle.

3.2.2 Construct measurement

The main purpose of this paper is to estimate the effect of program participation on TAV consumption, and to test whether the program theory - that increased production, knowledge, and attitudes would increase TAV consumption - was correct.

Outcome measure: Traditional African vegetable consumption

The main measure of TAV consumption was the maximum number of days per week any TAV was consumed in the household (0-7); this variable represented frequency of consumption. It was measured using a validated 7-day food frequency questionnaire [219].

The second main consumption indicator was average amount of TAVs preschool-age children consumed per day. If the household had a child age 2-5 years at baseline, the items on the food frequency questionnaire were asked for both the household and the reference child age 2-5 years. If the reference child consumed a TAV, the caretaker was asked to estimate how much of a standard bowl (provided) was filled by the portion the child ate. If the TAV was mixed with another kind of vegetable (e.g. kale), the mother estimated what proportion of the dish TAVs made up. (The standard bowl was a commonly-available dish that many of the respondents themselves had, so they found it easy to estimate the amount the child consumed.) At the research station, TAVs were weighed before and after cooking in the traditional fashion, in order to calculate the gram amount of TAVs in a bowl-full. The final indicator of amount children consume in **grams per day** is a composite indicator of consumption, calculated using frequency (times per week

TAVs were consumed) multiplied by gram amount typically eaten per sitting, and divided by seven (days in the week).

Exposure variables

TAV production was measured as (1) whether or not TAVs were grown and (2) how many TAVs (out of the five promoted) the household grew at any time during the 12 months before the survey.

Micronutrient knowledge was measured as a score of four survey responses:

1. When asked to name foods high in vitamin A, respondent listed any TAV as a food rich in vitamin A.
2. If the respondent listed TAVs as high in vitamin A, she could name a specific function of vitamin A.
3. When asked to name foods high in iron, respondent listed any TAV as a food rich in iron.
4. If the respondent listed TAVs as high in iron, she could name a specific function of iron.

Knowledge about iron and vitamin A specifically was measured because the nutrition-focused marketing of TAVs and nutrition information given to farmers rested primarily on the content of these two micronutrients in TAVs. Respondents only received points for listing a function of the micronutrient if they knew that it was contained in TAVs. Simply knowing what iron and vitamin A do for the body would not be expected to influence TAV consumption unless that functional knowledge was connected to TAVs specifically. Incorrect responses about micronutrient function were counted as long as they were specific, because in theory, any piece of nutrition knowledge could affect perceived value and motivate eating.

Medicinal knowledge was measured in the survey by asking respondents if they knew of any illnesses that any of the TAVs could treat. If the response was yes, the number of unique illnesses the household reported could be treated using TAVs was counted, to create a variable of "number of unique treatments known." Because using TAVs to treat iron-related illnesses (anemia, fatigue, geophagia) was common and, additionally, was related to TAV promotions based on iron content, a 0/1 categorical variable was also created, for whether the household reported a TAV could be used to treat iron-related illness.

Attitudes were measured as a score composed of responses to three questions, representing social acceptability/perceived status of traditional vegetable consumption, attitudes of genderedness of traditional vegetable consumption, and overall desire to consume traditional vegetables. The three questions asked to make up the scale were:

1. Do you offer traditional leafy vegetables when visitors come to your home? (yes/no)
2. Some people will not eat traditional leafy vegetables because they are not good food for men. How do you feel about this opinion? (Disagree, neutral, agree)
3. Would you like to consume more, less, or the same amount of traditional leafy vegetables, compared to the amount you consume now? (more, same, less)

Since attitudes are inherently a qualitative concept, it is difficult to find a satisfactory way to represent them numerically. Any scale unit will necessarily be somewhat arbitrary. In this case, the scale was constructed by assigning values to each response, based on the researcher's understanding of the likely meaning of the response, and then summing the values.

For the first question, whether the respondent serves TAVs to visitors, a negative response was culturally the status quo and considered neutral (0 points), and a positive response was historically unusual and considered to be very positive (2 points). In studies in Western Kenya and Northern Tanzania, even if people ate TAVs often, the vegetables were considered to be unfit for serving to visitors [185, 288]. In other parts of the world, distaste for serving traditional vegetables to guests has been linked to their low staus [41]. In the Western Kenya study, people explained their low status with the adage, "the hyena cries and still leaves it untouched" [185] (p 333), meaning that even an animal will go hungry rather than to eat the traditional vegetables.

For the second question, most people disagreed with the statement that "TAVs are not good food for men". This was found in focus group discussions of active program participants as well as in the survey responses. Therefore, if a respondent did not disagree - i.e. if she either agreed or felt neutral - the response was given a score of -2 points, since that represented an uncommonly gendered attitude about the acceptability of TAVs. If the respondent disagreed, the response was given a score of 0 points, since that response was the "norm". The question mainly arose from qualitative inquiry in Tanzania: because of the Maasai cultural heritage of the Wa Arusha, hunting and animal-source foods are of great importance, and men traditionally did not consume any greens except as medicinal treatments. The cultural belief that consuming vegetables is appropriate for women only, and that meat is the food for men, has been seen in other cultures as well [243].

For the third question, most people reported wanting to consume more TAVs. Because that response was so common, it was given 1 point - clearly a positive attitude, but perhaps less strikingly positive than serving TAVs to visitors. Wanting to consume less was a somewhat uncommon response and received a score of

-2 points: a strongly negative response. Wanting to consume the same amount as currently consuming received a score of 0 points, unless the respondent never ate TAVs, in which case it was considered negative and received -2 points.

The attitude scale after summing the values of these three questions ranged from -4 to +3.

Marketability and price are hypothesized to be important to consumption, but are not testable in the main models. TAV marketability had to do with overall social acceptance and interest in TAVs in the sites (Nairobi and Arusha), and did not vary by household. The program aimed to create markets through overall promotional efforts and connecting farmer groups to buyer organizations. Information on marketability shifts was derived from observations, interviews and focus group discussions among the small farmers. Price was measured at the household level as mean price obtained per kg TAV sold, but because less than half of all households surveyed sold any TAVs, price could not be included in models to conserve statistical power.

3.2.3 Focus group discussions

To improve understanding of the constructs to be measured and the context of the survey, focus group discussions (FGDs) were held before the follow-up survey took place. In all, 22 FGDs were held: 15 in Kiambu (5 women-only, 5 men-only, and 5 mixed gender), and 7 in Arusha (2 women-only, 1 men-only, 4 mixed gender). The average number of participants in each group was 11. Participants were selected based on membership in a farmer group which was growing TAVs, and voluntary expression of interest to participate. The setting for each FGD was usually in a central community meeting place such as a school, hall, or church. Each FGD lasted approximately 30-60 minutes, and covered topics such as what motivated TAV production and consumption, whether respondents had witnessed a shift in attitudes in recent years, marketing opportunities, and perceived health benefits of TAVs. Discussions were simultaneously interpreted between English and Kikuyu/Kiswahili by collaborators who were fluent in both languages and had extensive previous experience conducting FGDs for research. Information discussed was recorded as notes.

3.2.4 Statistical methods

Descriptive statistics were described using Pearson chi-square test for difference in proportions, and independent samples t-tests for differences in means (between program and comparison groups). Longitudinal analyses were carried out as mixed effects models, examining the variables of interest as fixed effects, and controlling for district and village as random effects, where all independent and dependent variables of interest are differenced (time 2-time 1). This technique controls for household level unobserved fixed effects and thereby substantially rids the model of endogeneity. Model fit was determined using -2 restricted log likelihood chi-square tests. All analyses were carried out in PASW statistical software (version 18.0) [247].

For most analyses, participant and comparison groups were analyzed as intention-to-treat. However, not all participant households were still active participants by the follow-up survey: 31% of participants at baseline had stopped participating in the program in Kiambu, and 49% had stopped participating in Arusha. They were still interviewed at follow-up to test hypotheses related to program theory, but some analyses grouped baseline-only participants separately from consistently active participants in analyses of program effect. The intention-to-treat analysis is justified throughout most of the analyses in this paper because baseline-only participants heard many of the messages associated with the program's promotion of TAVs based on nutrition, but may not have received seeds or joined groups to take advantage of the income-generation part of the program.

3.3 Results

3.3.1 Baseline household characteristics

Baseline characteristics of the sample are shown in Table 3.1.

Table 3.1: Baseline characteristics of households

	Kenya			Tanzania		
	Comparison	Program	p	Comparison	Program	p
	n=77	n=92		n=76	n=93	
Years of school (head)	9.0	8.6	0.487	6.3	6.6	0.525
Years of school (mother)*	8.9	8.3	0.302	6.3	6.8	0.232
% female-headed households	13.0	13.0	0.991	14.7	16.1	0.794
Wealth (asset ownership, geometric mean)	$820	$1433	0.004	$695	$655	0.797
Land size (acres)	1.1	2.2	<0.001	2.3	4.0	<0.001
Age of household head (years)	43	52	<0.001	39	43	0.008
Household size	5.0	4.8	0.627	6.7	6.4	0.443
Number of children under age 5	1.3	0.5	<0.001	1.5	1.3	0.103
% of age 2-5 children <-2 WAZ	8.0%	20.8%	0.185	11.9%	12.6%	0.194

* The household "mother" (the person who cared for the reference child age 2-5 years or if no reference child, the person who prepared the majority of the household food) was sometimes the same as the head of the household, but usually not.

Households that joined the program were not entirely comparable to a random selection of households in comparison villages. At baseline, the program households were on average richer, had more land, were older, and had fewer children age 2-5 years.[1] The difference in land size in both sites may represent self-selection bias of those who chose to join the program. Self-selection bias is more apparent in variables that reflect TAV use. As seen in Tables 3.2 and 3.3, the program households also were more likely to have grown TAVs, eaten TAVs more frequently, and served more TAVs to children than comparison households. In Kiambu, participants also started the program with more knowledge and more favorable attitudes about TAVs than comparison households, although in Arusha those differences were not observed. It appears that people who chose to participate were already more familiar and more interested overall in TAVs than a random sample of households with children in a similar nearby village.

3.3.2 How program participation is related to consumption

Controlling for wealth, change in wealth, household head age, and baseline consumption, program participation is significantly associated with change in frequency of TAV consumption in Kiambu (Table 3.4). Program participants in Kiambu ate TAVs about 1.25 day/week more frequently at followup than baseline, which was a change of over 1 day more than than that observed in the comparison group. Children in participant households in Kiambu also increased their TAV consumption by 23 g more per day than did comparison households.

In Arusha, program households appeared to reduce their TAV consumption less than did comparison households over the same time period, but this difference was

[1] As described in Chapter 2, though, program households in Kiambu were actually younger and less wealthy than other households in their villages, so those differences between program and comparison groups here reflect incomparable villages rather than self-selection bias.

Table 3.2: Household TAV production and use at baseline: Kiambu, Kenya

	Comp.	Prog.	p	Sample
% growing TAVs	40.3	88.0	<0.001	All
Number of TAVs grown (out of 5)	0.69	2.33	<0.001	All
Harvest (among those growing) (kg/6-mo season) (geometric mean)	64.72	298.87	0.003	Those who grew TAVs (n=70)
Area planted in TAVs (acres) (does not include 0s)	0.034	0.079	0.019	Those who grew TAVs (n=100)
% households where women are in charge of production	85.2	68.8	0.097	Those who grew TAVs (n=107)
% households where women decide whether to plant TAVs	83.3	69.7	0.191	Those who grew TAVs (n=100)
% households consuming TAVs	49.4	77.2	<0.001	All
Frequency of consumption (days/week)	1.27	2.54	<0.001	All
Number of TAVs consumed	0.79	1.63	<0.001	All
Amount consumed by children (g/day) (incl. non-consumers in means)	12.95	33.90	0.001	Those with children age 2-5 years
Micronutrient knowledge score	0.18	0.55	0.002	All
Attitude score	0.49	1.35	0.002	All
Number of medicinal uses of TAVs	0.83	1.71	<0.001	All
% reporting that TAVs treat iron-related illness	13.0	19.6	0.252	All

Notes: Equality of proportions was tested using Pearson chi-square test statistic. Equality of means was tested using t-tests for independent samples. For t-tests, significance levels were identical or nearly identical for each test whether equal variances were assumed or not assumed; results where equal variances were not assumed are reported.

not statistically significant at the $p<0.05$ level between program and comparison households (Table 3.4). Program households significantly increased the number of different species of TAVs they ate compared to comparison households. There appeared to be a large difference between program and comparison households in

Table 3.3: Household TAV production and use at baseline: Arusha, Tanzania

	Comp.	Prog.	p	Sample
% growing TAVs	48.7	64.5	0.038	All
Number of TAVs grown (out of 5)	0.86	1.09	0.165	All
Harvest (among those growing) (kg/6-mo season) (geometric mean)	100.48	206.44	0.182	Those who grew TAVs (n=67)
Area planted in TAVs (acres) (does not include 0s)	0.48	0.44	0.844	Those who grew TAVs (n=79)
% households where women are in charge of production	82.4	67.8	0.127	Those who grew TAVs (n=93)
% households where women decide whether to plant TAVs	80.6	75.9	0.607	Those who grew TAVs (n=89)
% households consuming TAVs	84.2	92.5	0.091	All
Frequency of consumption (days/week)	3.04	3.85	0.025	All
Number of TAVs consumed	1.86	2.08	0.230	All
Amount consumed by children (g/day) (incl. non-consumers in means)	47.93	71.87	0.014	Those with children age 2-5 years
Micronutrient knowledge score	0.79	0.82	0.863	All
Attitude score	2.37	2.46	0.667	All
Number of medicinal uses of TAVs	0.45	0.55	0.393	All
% reporting that TAVs treat iron-related illness	7.9	5.4	0.509	All

Notes: Equality of proportions was tested using Pearson chi-square test statistic. Equality of means was tested using t-tests for independent samples. For t-tests, significance levels were identical or nearly identical for each test whether equal variances were assumed or not assumed; results where equal variances were not assumed are reported.

grams of TAVs children consumed, but the variability of changes was also large and the program effect was not significant.[2]

[2]These results, controlling for potentially confounding variables that differed at baseline, are similar to the analysis for probability of a program effect (without controls), but the parameter estimates here are probably less biased and have more precise standard errors.

Table 3.4: Change in TAV consumption based on program participation

	Δ Frequency (days/week TAVs consumed)	Δ Diversity (# of TAVs consumed)	Δ Amount (grams/day of TAVs consumed by children)*
	Est. [S.E.]	Est. [S.E.]	Est. [S.E.]
Kiambu	n = 164	n = 164	n = 83
Program group (n=89)	1.231 [0.237]	0.404 [0.171]	22.367 [6.648]
Comparison group (n=75)	0.229 [0.256]	0.254 [0.177]	1.649 [3.992]
Difference (p-value)	1.002 (0.003)	0.149 (0.358)	20.718 (0.011)
Arusha	n = 159	n = 159	n = 118
Program group (n=87)	-0.362 [0.427]	0.294 [0.130]	-2.720 [8.387]
Comparison group (n=72)	-1.217 [0.437]	-0.600 [0.140]	-25.139 [8.389]
Difference (p-value)	0.855 (0.074)	0.894 (0.004)	22.419 (0.138)

Means are adjusted for baseline wealth, change in wealth, age of household head, and baseline consumption as fixed effects, and district and village as random effects. * In addition to the above control variables, means are adjusted for change in household size and change in number of days the child was sick in the 2 weeks prior to the survey.

Because a substantial number of program "participants" stopped attending program meeting between baseline and follow-up, change in TAV consumption was also compared between comparison households, households that participated at baseline only (and subsequently stopped), and active program participants. The results are shown in Table 3.5. When comparing change in consumption by *active* participation status, a dose-response relationship is seen, where in both sites, active participants had the most positive change in consumption, and comparison households the least positive change. In both countries, change in both frequency and amount of consumption in the active participant group is statistically significantly different from changes in the comparison group.

Table 3.5: Change in TAV consumption by active participation status

	Δ Frequency (days/week TAVs consumed)	Δ Diversity (# of TAVs consumed)	Δ Amount (grams/day of TAVs consumed by children)*
	Est. [S.E.]	Est. [S.E.]	Est. [S.E.]
Kiambu	n=164	n=164	n=83
Active program participants (n=58)	1.358 [0.281]	0.467 [0.187]	20.996 [8.786]
Baseline-only participants (n=31)	1.023 [0.371]	0.307 [0.216]	23.910 [9.464]
Comparison group (n=75)	0.220 [0.246]	0.250 [0.171]	1.669 [4.005]
Difference between active and comparison (p-value)	1.138 (0.003)	0.217 (0.249)	19.327 [0.056]
Arusha	n=159	n=159	n=118
Active program participants (n=44)	-0.059 [0.512]	0.446 [0.176]	-3.891 [10.860]
Baseline-only participants (n=43)	-0.669 [0.512]	0.138 [0.176]	-1.671 [10.619]
Comparison group (n=72)	-1.228 [0.479]	-0.603 [0.142]	-25.174 [8.336]
Difference between active and comparison (p-value)	1.169 (0.042)	1.050 (0.005)	21.283 (0.171)

Means are adjusted for baseline wealth, change in wealth, age of household head, and baseline consumption as fixed effects, and district and village as random effects. * In addition to the above control variables, means are adjusted for change in household size and change in number of days the child was sick in the 2 weeks prior to the survey.

3.3.3 How production, knowledge, and attitudes are related to consumption

The program theory was that increased production, nutrition knowledge, and attitudes would increase TAV consumption. An additional hypothesis was that increased medicinal knowledge would be associated with increased consumption. The results of these hypothesis tests are presented here. In Kiambu (Table 3.6), changes in production, medicinal knowledge, and program participation were associated with change in household consumption. Only program participation was associated with increased child consumption; children in program participant households increased TAV consumption by 21g per day on average more than those in comparison households.

In Arusha (see Table 3.7), more positive attitudes, change in medicinal knowledge, and program participation were associated with change in household consumption. Gaining knowledge that TAVs could be used to treat iron-related illness was associated with increased frequency of consumption and also was associated with a 26-gram increase in amount of TAVs preschool-age children consumed daily ($p=0.016$). Medicinal knowledge was the only variable associated with change in child consumption in Arusha.

Medicinal knowledge and program participation were associated with changes in household consumption in both countries, while production was only a significant predictor of consumption in Kiambu, and attitudes were only significant in Arusha. Production may not have been a significant factor in Arusha because the practice of wild collecting vegetables appeared to be more prevalent there (based on observation), which could have substituted for production. Wild collection sometimes occurred even in the farmers' own fields, if the TAVs grew as weeds. Attitudes may have been more significant in Arusha than Kiambu simply because the indicator was a better measure there; for example, the gendered consumption question in the scale mostly applied to Tanzania. The program effect was much larger in Kiambu than Arusha, and may have picked up some sort of attitude changes that were not well measured in the attitude variable.

Table 3.6: Change in consumption based on changes in production, knowledge and attitudes, Kiambu, Kenya

	Δ Frequency		Δ Amount (g/day)	
	n=154		n=77	
	Est. [S.E.]	p	Est. [S.E.]	p
Δ production (# TAVs cultivated)	0.246 [0.117]	0.038	-0.595 [2.504]	0.813
Δ attitude score	0.083 [0.089]	0.353	0.684 [1.998]	0.733
Δ micronutrient knowledge score	0.155 [0.135]	0.252	-3.295 [3.646]	0.369
Δ medicinal knowledge (# treatments known)	0.247 [0.124]	0.048	0.762 [2.646]	0.774
Δ wealth (value of assets owned)	-0.006 [0.014]	0.649	0.117 [0.296]	0.695
Baseline wealth (log value of assets owned)	-0.071 [0.145]	0.624	-1.036 [2.915]	0.723
Household head age (years)	0.003 [0.012]	0.827	0.661 [0.290]	0.821
Program participation	1.088 [0.352]	0.002	20.901 [8.741]	0.020
Δ Household size	-	-	-2.590 [4.601]	0.575
Δ days child sick in last 2 weeks	-	-	-0.267 [0.928]	0.774
Baseline TAV consumption (days/week)	-0.554 [0.088]	<0.001	-0.820 [0.162]	<0.001

All variables listed were treated as fixed effects; analyses also controlled for district and village as random effects.

For predicting child consumption, small sample size limited the power to detect associations in Kiambu, although program participation was still significant. It is an important observation that increase in medicinal knowledge in Tanzania - measured as gaining knowledge that TAVs could be used for iron-related illness - was strongly related to the amount fed to children. Household medicinal knowledge

Table 3.7: Change in consumption based on changes in production, knowledge and attitudes, Arusha, Tanzania.

	Δ Frequency		Δ Amount (g/day)	
	n=154		n=116	
	Est. [S.E.]	p	Est. [S.E.]	p
Δ production (# TAVs cultivated)	0.076 [0.104]	0.468	0.441 [3.296]	0.894
Δ attitude score	0.222 [0.083]	0.008	4.108 [2.314]	0.079
Δ micronutrient knowledge score	0.020 [0.105]	0.851	-0.292 [3.207]	0.928
Δ medicinal knowledge (TAVs used for iron-related ailment)	1.264 [0.345]	<0.001	26.368 [10.758]	0.016
Δ wealth (value of assets owned)	0.016 [0.016]	0.307	0.582 [0.485]	0.233
Baseline wealth (log value of assets owned)	-0.163 [0.104]	0.119	-1.455 [3.109]	0.641
Household head age (years)	0.023 [0.014]	0.091	0.554 [0.430]	0.201
Program participation	0.622 [0.302]	0.041	17.745 [10.867]	0.182
Δ Household size	-	-	-4.514 [3.553]	0.207
Δ days child sick in last 2 weeks	-	-	-0.237 [0.899]	0.793
Baseline TAV consumption (days/week)	-0.754 [0.067]	<0.001	-0.886 [0.078]	<0.001

All variables listed were treated as fixed effects; analyses also controlled for district and village as random effects.

may be a stronger motivator of consumption than was expected.

3.3.4 How program participation and time are related to changes in knowledge and attitudes

Change over time

The program aimed to change attitudes and nutrition knowledge in the whole program area, so the change over time between baseline and follow-up was assessed for the whole sample (see Table 3.8). In Kiambu, attitudes about TAVs did become significantly more positive, increasing by 0.76 points on the attitude scale ($p<0.001$). Attitude scores started higher in Arusha, at 2.42 points, and did not increase over the year. In Kiambu, micronutrient knowledge also increased significantly over the whole area, by 0.22 points ($p=0.03$). Micronutrient knowledge did not change in Arusha, but medicinal knowledge of uses of TAVs increased significantly, by an average of 0.36 additional illness treatments known at follow-up ($p<0.001$).

These results over time illustrate why the testing of the effects of knowledge, attitudes and production on consumption, rather than just program participation, is such an important part of this study: because the program may have influenced attitudes and knowledge over the whole area, rather than just among participants.

Change based on treatment group

There may be little difference between treatment groups for nutrition knowledge and especially attitudes, since promotional efforts were not limited to program participants.

In Kiambu, there was a significant relationship between program participation and change in micronutrient knowledge dependent on mothers' education (results table not shown). Among program participants, for each additional year of

Table 3.8: Change over time within the whole sample

Site	Construct	Baseline mean (s.d.)	Follow-up mean (s.d.)	Mean change (p-value)
Kiambu	Attitude score (n=160)	0.98 (1.73)	1.74 (1.47)	0.76 (<0.001)
	Micronutrient knowledge score (n=169)	0.38 (0.83)	0.60 (1.04)	0.22 (0.033)
	Medicinal Knowledge (# treatments known) (n=169)	1.31 (1.15)	1.28 (1.24)	-0.024 (0.856)
Arusha	Attitude score (n=165)	2.42 (1.23)	2.45 (1.12)	0.038 (0.775)
	Micronutrient knowledge score (n=169)	0.80 (1.04)	0.97 (1.03)	0.17 (0.143)
	Medicinal Knowledge (# treatments known) (n=169)	0.50 (0.77)	0.86 (1.04)	0.36 (<0.001)

mother's education, micronutrient knowledge score increased 0.106 points more than among non-participants.

In Arusha, no program effect on micronutrient knowledge was observed, although each additional year of maternal education was associated with a 0.107-point increase in micronutrient knowledge score. In sum, higher maternal education, particularly in the program group in Kiambu, was associated with greater change in micronutrient knowledge about the vegetables.

Change in medicinal knowledge about TAVs was not associated with program participation in Kiambu. In Arusha however, there was an interaction between program group and maternal education: among program participants only, each additional year of mothers' schooling was associated with an increase in knowledge of 0.115 unique illnesses cured by TAVs. Each year of Arusha program participant mothers' education was also associated with a 40% greater chance of gaining knowledge that TAVs could treat anemia than among non-participants. Education thus appeared to be related to acquiring both micronutrient and medicinal knowledge.

No difference was observed in change in attitudes in the program group vs. comparison in either country. That is expected, because promotional efforts about TAVs were not limited to program participants; rather they were widespread across the region. Therefore for attitude changes, there was effectively no control group.

3.3.5 Farmers are producers, as well as consumers: Are knowledge and attitudes related to the decision to produce?

The relationship between program outputs and TAV production is shown in Table 3.9. Program participation was the most significant factor in predicting change in TAV production in both countries. In Kiambu, participation was associated with planting 0.80 more TAVs ($p=0.001$) compared to the comparison group; in Arusha participation was associated with planting 0.98 more TAVs ($p<0.001$).

Change in medicinal knowledge was the only other factor predicting change in TAV production: for each new unique use of TAVs learned in Arusha, 0.22 more TAVs were planted ($p=0.020$). In Kiambu, increased medicinal knowledge was marginally related to increased number of TAVs cultivated ($p=0.060$). Change in knowledge or attitudes did not reach significance in either country.

Table 3.9: Change in TAV production (number of TAVs grown) based on changes in knowledge and attitudes

	Kiambu, Kenya		Arusha, Tanzania	
	n=154		n=154	
	Est. [S.E.]	p	Est. [S.E.]	p
Δ attitude score	-0.017 [0.052]	0.744	0.088 [0.054]	0.105
Δ micronutrient knowledge score	-0.010 [0.052]	0.903	0.064 [0.069]	0.350
Δ medicinal knowledge (# treatments known)	0.138 [0.073]	0.060	0.217 [0.093]	0.020
Δ wealth (value of assets owned)	-0.000 [0.009]	0.998	-0.005 [0.111]	0.634
Baseline wealth (log value of assets owned)	0.082 [0.089]	0.356	0.005 [0.070]	0.941
HH head age (years)	-0.004 [0.007]	0.617	0.001 [0.009]	0.082
Program participation	0.810 [0.239]	0.001	0.976 [0.193]	<0.001
Δ land size (acres)	-0.025 [0.059]	0.667	-0.014 [0.023]	0.551
Baseline TAV consumption (days/week)	-0.620 [0.082]	<0.001	-0.770 [0.092]	<0.001

All variables listed were treated as fixed effects; analyses also controlled for district and village as random effects.

3.3.6 Reasons for eating TAVs: survey and qualitative inquiry

Qualitative results from FGDs lend further evidence to the relationships between production, knowledge, attitudes, and consumption, within the larger context of growing the vegetables for sale.

The primary reason households reported being interested in growing TAVs with the TF Project was the marketing potential; home consumption was secondary in most cases. Farmers reported consuming most everything they grow on farm, however. Respondents reported, "We get food from the farm mostly - instead of going to buy foods, we pick the foods we grow." It might be expected that the more farmers eat of the TAVs they grow, the less money they are able to make from their sale, and therefore there is a clear opportunity cost of household TAV consumption. Qualitative evidence does not support this assumption. The overwhelming evidence from focus group discussions and farmer interviews was that many farmers do not perceive an economic loss from consuming TAVs at home.

Farmers universally reported that selling 100% of their home-grown vegetables would not make sense, since they would simply have to "turn around and buy others." This implies that either the retail price of most vegetables is higher than the farmgate price farmers could receive for TAVs, or that farmers also considered the hassle of going to market a significant cost, when they could simply gather food for dinner outside their doorstep. The statement also indicates that vegetable demand in these communities is relatively inelastic: farmers were not willing to go without eating vegetables. The clearest reason for this was taste and enjoyment of food, bolstered by cultural norms of vegetable-eating particularly in Kiambu, but nutritional reasons for maintaining vegetable consumption were also apparent. FGD respondents said, "People will grow *sukuma* (kale) and go uproot the *terere* (amaranth) that is growing - it's ignorance. Lack of knowledge - some people don't know *terere* is more valuable than the others, and just leave it." and, "We had not been eating them till we realized the value they're adding. Now people have come to agree that TAVs are a good part of the diet."

These quotes represent the importance of knowledge in encouraging consumption. Medicinal knowledge also was frequently discussed and appeared to be a consumption motivator. Several people relayed stories of healing their own anemia or joint problems by eating TAVs every day. Advice from health professionals also seemed to encourage consumption for therapeutic/functional purposes: "Before, the Wa Arusha were using lots of meat. Other tribes used vegetables from the start. Now they go to the clinic and are advised to eat vegetables."

Attitudes and nutrition knowledge also surfaced frequently in FGDs as motivators of consumption. One respondent said, "Some people are prejudiced against TAVs - they'll leave mlenda (a traditional vegetable), and say it's for the Ugandans. Some say that TAVs are a poor man's food. Some people are shocked when they find you eating managu (nightshade)." Another indicated that societal attitude shifts might have been influencing the farmers' own attitudes and propensity to consume TAVs: "Now rich people are eating TAVs...they even sell them in the supermarket...so we take notice, like maybe we should eat them too."

The survey questionnaire also gathered useful responses about the main reasons respondents chose to eat TAVs, of those who consumed any TAV in the last week (see Table 3.10). The most common reasons given for consuming TAVs were nutrition and health in both Kiambu and Arusha. "Taste" was a common answer in Kiambu, though less common in Arusha, and availability was given by about one quarter of the sample in each site. Tradition was also a moderately important reason for consumption in Arusha.

Table 3.10: Among households that consumed TAVs, main reasons for consumption

Reason	Kiambu (n=109)	Arusha (n=151)
Nutrition/health reasons	73%	72%
Taste	45%	8%
Availability	19%	29%
Tradition	5%	15%
Price	3%	6%

Note: each household could give multiple reasons.

Among households who did *not* consume any TAVs in the week prior to the survey, the main reason in both countries was lack of availability: 65% in Kiambu, and 73% in Arusha. In Kiambu, the second most common reason was "taste," given by 27% of the sample, and finally unfamiliarity, given by 2% of the sample. The remainder stated other reasons, including illness, lack of time to gather the vegetables from the wild, or lack of time to get to market.

Among households where preschool-age children did not consume TAVs in the week prior to the survey, the main reason in both countries was that no one in the household consumed them; that is, TAVs were not prepared. 95% in Kiambu and 94% in Arusha stated that reason. In Kiambu, 18% also stated that the child did not eat TAVs because he/she did not like the taste; no mother in Arusha gave that reason. A small percentage gave other reasons for the child not eating TAVs, such as the child being away during the week. It is interesting that in all but one of the households in Kiambu where the child "not liking TAVs" was reported to be a reason for not consuming them, the TAVs were not prepared for anyone in the household. This likely reflects intra-household bargaining between the mother and child: since everyone eats "from the same pot" at meals, if a child refuses TAVs, the mother may be more likely to select a different food to cook for the whole household, so that the young child will also eat. In this way, the child's taste preferences may affect the household diet.

In general however, according to qualitative inquiry in both sites, children generally accept TAVs, particularly the sweeter types: amaranth, sweet potato leaf, and early-picked cowpea leaf and nightshade. They did not prefer spider plant and late-picked[3] nightshade as much, which were more bitter, and late-picked cowpea leaf, which was tougher. However, mothers reported that children would still eat even the more bitter vegetables if they were mixed together with some sweeter ones. Children were observed eating TAVs, although on at least one

[3]Nighshade can be harvested several times from the same planting, with each successive harvest tasting slightly more bitter. Early harvests are sweeter, and by the third or fourth harvest, the taste gets bitter.

occasion a child was observed refusing nightshade (cooked by itself) after taking a few bites, because it was too bitter. Extended blanching was one technique to reduce bitterness, used in other regions of Kenya, but mothers in these study sites generally preferred mixing different kinds of TAVs to reduce overall bitterness to blanching - which is preferable in retaining micronutrient content as well.

3.4 Discussion and conclusions

Results showed that production, nutrition knowledge, and attitudes were each important predictors of TAV consumption, to varying degrees in the two different program/study sites. Results initially emanating from focus group discussions with farmers also elucidated that two important influences on farmer TAV consumption were missing from the initial conceptual framework: knowledge about the medicinal value of TAVs, and the influence of consumer attitudes on farmer esteem for TAVs. Overall environment of marketability and expectation of income also influenced the decision to grow TAVs, but price of TAVs did not seem to be a major influence on consumption. The revised conceptual framework is shown below (Figure 3.2).

It follows that having a market also may have had an effect on farmers' own attitudes about social desirability of the food. If a food is sold in markets, particularly to city or upper-class consumers, it may spark an interest in consuming that crop for the growers themselves.

There were other promotions of TAVs besides the TF project in Kenya (through media, not interacting directly with farmers) which likely affected knowledge and attitudes. These promotions probably would have affected program and comparison groups equally.

Another probable secular change was that TAV production and sales were likely

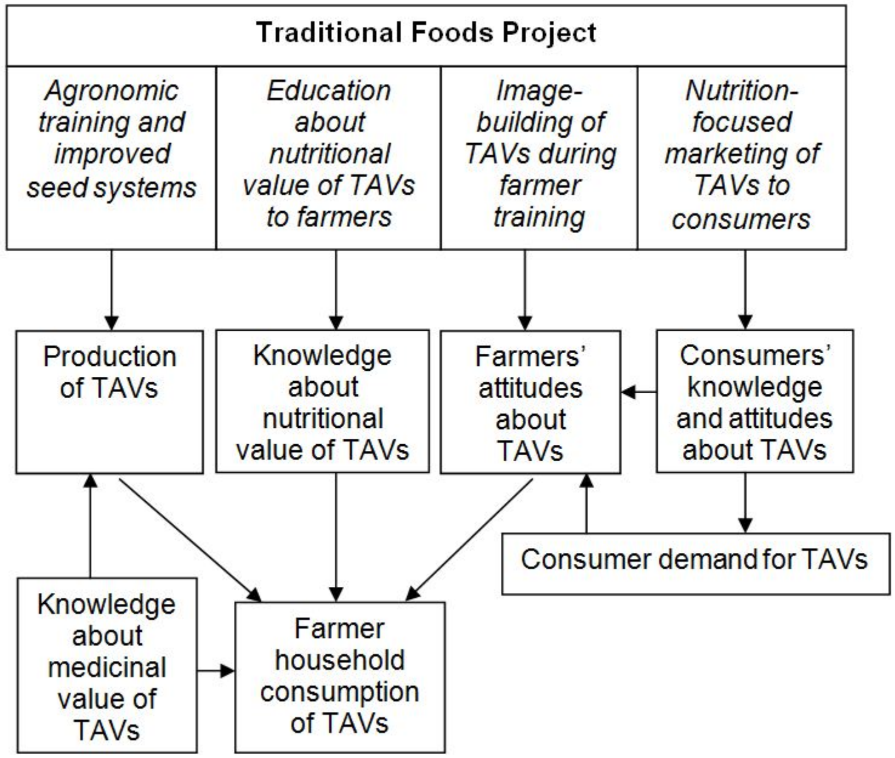


Figure 3.2: Revised Conceptual Framework

depressed in 2008, compared to 2007, due to 2008 post-election violence in Kenya. Many farmers reported being unable to sell their crops in Jan-Feb '08 due to impassable roads; fear of continued violence may have influenced them to grow fewer crops for sale, if they thought they might be unable to sell them. This also would likely have affected program and comparison groups equally.

This study had a very low rate of loss-to-follow-up (5%), which means there is little chance of those surveyed being a biased sample of the baseline selection. The analysis of households lost to follow-up in Appendix C confirms that no probable bias was observed.

The analysis technique of using a first difference model to examine associations longitudinally within households is a very strong analytical technique that makes causal inference more likely. Results shown here, difference of differences, are the gold standard for program evaluation design.

This analysis is not without limitations however. Although the best possible evaluation technique was used, self-selection bias was present, as seen in significant differences in variables at baseline. Program participation was a choice in the villages where the program was operating, so there was no way to avoid self-selection bias. There could be residual endogeneity: the same (mostly unmeasurable) factors that made farmers join the program may be the same factors that make them more prone to increasing TAV consumption. However, the effects of independent variables appeared to be statistically the same between program and comparison groups.

Small sample size may have had limited ability to detect significant associations. The short time frame also may have limited magnitude of changes seen. Since some associations were seen however, these limitations actually increase confidence in the results.

Another limitation was that only a limited number of TAVs were included. It is possible that some people were high consumers of *other* TAVs, but appeared low TAV-consumers because consumption of only five TAVs was measured. However, these five (especially three: amaranth, nightshade, and spider plant) were the most popular and were actively promoted, so it is unlikely. Also, in the knowledge and attitude questions, these five TAVs were asked about specifically, so the knowledge and attitude measurements are specific to consumption of those particular TAVs.

Bias is unlikely in the measurement of TAV consumption because the food frequency questionnaire intentionally covered many kinds of foods. TAVs comprised five food items midway through the FFQ to try to avoid cuing respondents that the survey was aimed at measuring TAV consumption. The FFQ was designed and validated to avoid bias, in that the first item was a food that most people ate every day (ugali), and the second item was a food that few people ever ate (whole raw chili peppers). The aim was so that respondents would feel comfortable answering honestly at either the low or high end of consumption of any of the food items. Random misclassification is a typical problem in food frequency questionnaires, but there is low chance of systematic bias in TAV measurement.

Random misclassification was likely present, especially in measurement of TAV consumption (FFQ) and medicinal uses measurement. This would reduce significance of associations, so the presence of random misclassification increases confidence in associations that were observed.

The results shown here, based on a strong analytical design, indicate that the program did appear to affect consumption of TAVs directly, and through the pathways of increased medicinal knowledge, more positive attitudes, and greater production of TAVs on the farm. In the first difference models, nutrition knowledge did not appear to influence change in TAV consumption, although some respondents in focus groups reported enhanced knowledge of health effects as a motivator for consumption. The health effects referred to could have been interpreted primarily as medicinal attributes of the TAVs, which strongly influenced consumption in both countries. Consumer willingness to pay for TAVs and societal attitude shifts based on factors outside the program, particularly in Kiambu, seemed to have an influence on farmers' own attitudes about TAVs. Given the validated program theory, other interventions promoting traditional foods for nutrition and public health could aim to increase production, attitudes, and knowledge - recognizing that knowledge encompasses traditional concepts of medicinal use, which may be a more important motivator of consumption than knowledge of biochemical nutrient content. These factors can be effective in counteracting prevailing stigma against traditional foods that are valuable resources for nutrition.

CHAPTER 4

TRADITIONAL VEGETABLE CONSUMPTION IN CENTRAL KENYA AND NORTHERN TANZANIA IS RELATED TO PERCEIVED MEDICINAL VALUE

4.1 Introduction

The distinction between nutritive and medicinal value of foods can be considered a false dichotomy. Many of the healing properties of plant foods are explained by micronutrients, but many more still are based on phytochemicals and physical properties. Indigenous and traditional knowledge systems often blend these constructs seamlessly in an overall perception of health benefit. Traditional foods contribute substantial nutritional and health benefits to diets in sub-Saharan Africa, but stigma against traditional, wild and semi-cultivated foods threatens their continued use. Efforts to promote traditional African vegetables around urban centers of Nairobi, Kenya and Arusha, Tanzania are currently underway. Nutrition-focused marketing - advertising based on the nutritional content and resultant health benefits of a food - is one strategy to increase demand for traditional vegetables. Nutrition messages may, however, fail to reach certain vulnerable populations if messages are framed in the scientific language of micronutrient content rather than more holistic health benefit. This research examines how smallholder farmers in program areas frame their knowledge about health benefits of traditional vegetables, and how medicinal knowledge is related to traditional vegetable consumption as food.

For most of human history, before nutrients were discovered, plant foods were consumed mainly for their medicinal properties - their good effect on health, as both preventative and curative of disease. Religious and secular texts from virtually all regions of the world refer to healing properties of foods, particularly herbs, and many un-recorded uses of foods as medicine continue today. While this is most often studied in the field of ethnobotany in indigenous or traditional societies, it is true in Western societies as well; for example the use of mint tea and ginger as remedies for stomach upset and nausea, chicken soup for sore throats, and prune juice for constipation.

Many of the healing properties of plant foods can be explained through micronutrient (such as the use of limes to prevent scurvy on long sea voyages); other properties are based on phytochemicals or physical plant components. The health effects of an indescribably large array of phytochemicals are not yet understood, although recent research has begun to describe some (e.g. lutein, resveratrol, capsaicin, lycopene, genistein, sulforaphanes, curcumin, etc.).

Traditional societies with limited knowledge of nutritional science continue to use plant foods simultaneously as food (motivated by need for calories and taste) and medicine (motivated by observation or knowledge of medicinal properties provided by consumption of the plant) [194, 64]. In several cultures (Ayurveda, Chinese, Vietnamese and Cuban traditional medicine to name a few), foods are classified in terms of hot-cold properties, and based on these are used therapeutically. Given a whole system of food classification based on health effects in the body, it becomes difficult to draw a line between food and medicine. Medicinal use, whether based on nutrient content or other botanical properties, may be an important motivator for plant consumption.

Evidence of this motivation has been documented in societies in East Africa. It appears that while plants consumed may have effects on specific diseases, they are also used as general prophylaxis. The Luo of Western Kenya consider a wide range of traditional vegetables to have distinct medicinal activities, including treating stomach ache, preventing edema in pregnancy, acting against tapeworms, diarrhea, and constipation, and counteracting measles [185]. A study that evaluated measles infection mitigation among the Maasai through "diet-based practices used to maintain child health" found that four commonly-used medicinal plants added to the diets of children significantly inhibited measles virus proliferation compared to control plants that were not used medicinally [188]. The authors reported: "When interviewed, mothers were asked to report the species they would employ to treat child measles infection. Mothers consistently responded that they used an array of plants to promote and maintain child health on a daily basis regardless of sick or healthy status" [188]. Other research has documented the practice of adding medicinal plants to foods of both healthy and sick children among the Maasai [117, 121]. Studies in northern Tanzania have also reported medicinal use of traditional vegetables. Informants in the East Usambara mountains reported that many kinds of wild leafy green vegetables "increase the amount of blood in the body" [279, 131]. In the Arumeru region of Tanzania, previous research reported that communities consider amaranth and pumpkin leaves to be "good for the eyes when eaten" [131]. In West Africa, researchers observed increased consumption of certain leafy vegetables in the rainy season, which had some anti-malarial activity in laboratory tests [65].

Disease prevention is not limited to communicable diseases or micronutrient deficiencies. Johns et al. [121] showed that plants frequently added to the mainly animal-source-based diets of the Maasai and Batemi in Tanzania had greater anti-cholestrolemic activity than a random sample of plants from the same environment not used in the diet, and hypothesized that herbal additives to food explain the paradox of low heart disease and and blood cholesterol among populations who consume milk and meat almost exclusively (and who consume over 65% of calories from fat). This hypothesis remains to be rigorously tested.

Traditional use of foods as medicine may be an important, and underutilized, part of both mitigating infectious disease and micronutrient malnutrition, as well as stemming the increase in chronic disease seen in all parts of the world, with the most rapid increases evident in sub-Saharan Africa [264]. It may be important for not only physiological effects, but also for its association with other cultural diet-related practices which as a whole could promote good health and nutrition.

4.1.1 Site description

Kiambu district, located just north of Nairobi, is made up of peri-urban and rural areas, where farmers grow primarily vegetables and tea. Although relatively close to Nairobi, access to the city is still challenging in areas of Kiambu where roads are in severe disrepair. The dominant ethnic group and language in Kiambu is Kikuyu.

Arumeru and Arusha districts surround the city of Arusha, Tanzania, a hub of East Africa for trade, international agencies and backpacker hostels near the slopes of Mt. Kilimanjaro and Mt. Meru. The dominant ethnic groups in the region are Meru, Maasai, and Wa Arusha, the latter also known as "sedentary Maasai," who are related to Maasai but for who have abandoned pastoralism for agriculture. Maasai pastoralists of Eastern Africa are an iconic tribe who retain many cultural traditions, such as dress and diet, even when they engage in city business. Links to Maasai culture among the Wa Arusha are strong, and many elderly women and men continue to use Maasai cultural practices learned in childhood. Maasai dietary and medicinal traditions are therefore directly relevant to discussion about Wa Arusha people.

In the rural areas of these districts, smallholder farmers make up the majority of the population. Nationally in Tanzania, over 2/3 of the rural population works full time on the farm, but in Arusha Region, this figure is 90% [275]. Most smallholder farms in the study region are integrated crop-livestock systems with maize and beans as the staple crops for home consumption; many have considerable experience in vegetable production. Agro-ecological conditions in Kiambu and Arusha are similar with high rainfall and mountainous topography, although Kiambu is higher in altitude and cooler, and Arusha has more marked rainy and dry seasons. Each of these subhumid areas is favorable for vegetable production, but suffers from low soil fertility from soil erosion due to hilly terrain and seasonal heavy rains, where ground cover is inadequate. Inherited landholdings have shrunk in size over the years in both places, due to population growth.

These areas, with agronomic potential and available markets in nearby urban centers, have the resources that can potentially support adequate livelihoods. Most farmers in these areas produce crops for sale, but struggle with uncertain marketing prospects and poor links with markets. Their resulting low incomes, combined with production that does not meet household needs, puts small farming households at chronic risk of malnutrition.

Current rates of child stunting are 32.4% in Central Kenya, which includes Kiambu, and 44.4% in Tanzania (though rates are likely to be lower than average in the Arusha and Arumeru districts) [136, 292]. Child underweight rates are 12.1% in Central Kenya [136] and 16.7% in Tanzania [292]. Nationwide in Kenya, an estimated 70% of children under 6 have sub-clinical vitamin A deficiency and 60% have iron-deficiency anemia. In Tanzania, vitamin A deficiency prevalence in young children is 37%; 65% of Tanzanian children have iron-deficiency anemia [271]. As for anthropometric indicators, micronutrient deficiency prevalence is likely somewhat lower than average in the study regions.

Side by side with the problems of undernutrition are rapidly growing obesity and chronic disease rates. As of 15 years ago, overweight exceeded underweight among women in both urban and rural areas of both countries [168]; while data are unavailable, East African experts indicate that obesity rates have greatly increased since then [141, 23], and new DHS surveys may start to collect data on obesity and chronic disease [135]. Between 2000 and 2030, a close to three-fold increase in diabetes and heart disease is predicted in sub-Saharan Africa [296]. These changes reflect the nutrition transition, marked by a shift to a diet high in sugar, fat, refined carbohydrates and processed foods and an increase in overweight, obesity and related chronic disease such as diabetes, hypertension, and cardiovascular disease [58, 204, 206]. Several studies have linked nutrition transitions to decline in traditional diets [211, 123, 118, 160].

4.1.2 Program context and study rationale

This research took place within the context of a program promoting production, marketing, and consumption of traditional African vegetables among small farmers in Kiambu, Kenya and Arusha, Tanzania. The Traditional Foods Project was designed and implemented as an income-generating program within the context of the dual burden of malnutrition . The goal of the program was to increase production and marketing of traditional African vegetables (TAVs) among small farmers, and to improve household income and nutrition. It was a three-year program implemented in both sites by the International Potato Center (CIP), the World Vegetable Center Regional Center for Africa (AVRDC-RCA), and Farm Concern International, a Kenyan non-profit organization. The program had four main components: (1) agronomic training and seed supply; (2) farmer cooperative formation and links to buyers; (3) a nutrition-focused marketing campaign, which used posters, flyers, demonstrations, and television to promote the image of TAVs among consumers, based on their nutritional content; (4) farmer training about the nutritional content of the vegetables.

There are hundreds of traditional African vegetables [32], but five were chosen for promotion in the TF Project based on their nutritional profile, their existing abundance in the sites' agroecosystems, and their popularity relative to other TAVs, which gave them a higher potential for marketability. All five of the TAVs were dark green leafy vegetables: amaranth (*Amaranthus* spp.), nightshade (*Solanum nigrum, S. scabrum, S. americanum*), African spider plant (*Cleome gynandra*), sweet potato leaves (*Ipomoea batatas*), and cowpea leaves (*Vigna unguiculata*).

The program used a nutrition-focused marketing strategy to boost esteem and demand for TAVs among both consumers and producers. The strategy focused on spreading information about the micronutrient contents of the crops. It did not specifically promote the crops based on medicinal properties, although in explanations of the function of iron and vitamin A in the body (iron improves blood and gives energy; vitamin A is important for immunity and eyesight), medicinal use could easily have been interpreted. Iron and vitamin A were the main micronutrients discussed in nutrition-focused marketing activities, because the TAVs stand out in content of those two nutrients. Calcium was also sometimes discussed. See Table 4.1 for nutrient values in comparison with kale and cabbage, which are also commonly consumed in the study regions.

The program was designed based on the idea that if consumers and farmers understand more information about the nutrient value of TAVs, they will be more motivated to consume them for health reasons. While this idea may be correct, it also is based on a somewhat Westernized view of "nutrition knowledge." Knowl-

Table 4.1: Nutrient Composition per 100 grams of African Traditional Leafy Vegetables

Nutrient	Amaranth	Spider flower plant	Nightshade	Cowpea leaf	Sweet potato leaf	Kale	Cabbage	RDA children age 1-8
Vitamin A (μg RAE)	477	558*	306	664	490	769	9	300-400
Vitamin C (mg)	64	13	20	56	70	120	32	15-25
Iron (mg)	8.9	6.0	1.0-4.2**	5.7	6.2	1.7	0.59	7-10
Calcium (mg)	410	288	442	256	158	135	47	500-800†
Zinc (mg)***	0.4-0.8	0.2-0.5	0.2-0.4	0.3-0.6	0.2-0.7	0.4	0.2	3-5
Folate (μg DFE)	85			101	80	29	43	150-200

Sources: All data for TAVs are from the FAO Food Composition Table for Use in Africa [151] except where noted. All data for kale and cabbage are from U.S. Department of Agriculture (USDA) Agricultural Research Service, National Nutrient Database for Standard Reference, Release 20 [277]. All values are for raw vegetables.
RAE = Retinol Activity Equivalent. Conversion rate of 12 units beta-carotene for 1 unit retinol used.
DFE = Dietary Folate Equivalent
†The value listed is an AI (Adequate Intake) rather than an RDA.
*Bioversity (IPGRI) data [33]
**Bioversity (IPGRI) data [60]
***AVRDC data [288]

edge about biochemical contents of vegetables may or may not be relevant, or fit within traditional knowledge frameworks, among the societies of rural farmers targeted. It is possible that exploration of traditional knowledge and knowledge frameworks about the health value of TAVs may be instrumental in understanding the type of knowledge which motivates eating behavior. Such traditional knowledge is likely to include medicinal uses of the plants targeted for promotion.

4.1.3 Objectives

The objectives of this study are:

1. To test whether medicinal knowledge is related to consumption in these sites;
2. To explore the sources of and influences on such knowledge, and whether medicinal knowledge has any relevance to nutrition behavior change interventions.

The principle hypothesis is that if people value TAVs for health-promoting properties, which may be expressed as medicinal properties, they will consume more of them.

Understanding how this kind of knowledge is relevant to nutrition interventions is important to the success of future interventions for both implementing organizations and communities targeted.

4.2 Methods

4.2.1 Study design and survey

This study utilizes two years of survey data collected from the same households. A baseline survey was done in each site immediately following recruitment of households into the program, and a follow-up survey was administered to the same households one year after baseline. The survey was administered to 358 farmer households at baseline (October, 2007); 181 households in Kiambu, Kenya, and 177 households in Arusha, Tanzania. In the one-year follow-up survey (October, 2008), five percent of households were lost to follow-up , mostly due to moving away. A total of 338 households were interviewed twice, 169 in each site.

Sampling frame

In each country, four districts were included in the study. Prior to the start of the study, program staff had selected four villages for the TAV program implementation, which were located in four different districts. Program staff reported that the main selection criteria for villages where the program would operate were prior experience producing horticultural crops, agronomic suitability for production, and proximity or access to markets. In keeping with the overall evaluation design, in each district, another village was selected based on similarity to the program village in size, wealth, proximity to markets, average household size, and public services availability. The survey was therefore administered in eight villages: four program villages, and four matched comparison villages. In each program community 25 households were interviewed, and in each comparison community, 20 were interviewed.

Respondent selection

In program villages, households to be interviewed were selected randomly from lists of program participants. In comparison villages, households were randomly selected from village census lists. The initial intent was to interview only households with children age 2-5 years, but that inclusion criterion was subsequently dropped due to many households who were recorded as having young children actually not having children in that age group. Therefore, households with preschool-age children were somewhat oversampled relative to the general population. Respondents within the household included three distinct roles: the person mainly responsible for agriculture, the person mainly responsible for TAV production, and the person mainly responsible for taking care of the reference child age 2-5 (or if no child, the person responsible for the majority of the cooking for the household). If a required respondent for a particular questionnaire section was temporarily unavailable, the interviewer made an appointment to return later in the day or week to complete the questionnaire with the appropriate respondent.

Household survey administration

The survey was administered over a period of four to five weeks simultaneously in both sites, in order to ensure comparable seasonality. The follow-up survey was administered exactly one year after the baseline also so that changes seen in agricultural production and TAV use were not due to differences in seasonality. Teams of interviewers administered the questionnaire in the local language of respondents, which was Kikuyu in Kenya, and Kiswahili, or occasionally Maasai, in Tanzania. During interviewer training, the importance of communicating consistent meaning of each question was emphasized, and role playing, discussion, and practice interviewing ensured that interviewers fully understood each question and agreed on its exact translation. The survey took one to two hours to complete for each household. Each day of the survey, research assistants and the PI reviewed the completed questionnaires, held a de-briefing session with enumerators, and returned any questionnaires with inadvertently missing information for follow-up.

Construct measurement

The questionnaire gathered information on household demographics, assets, income sources, agricultural production (particularly focused on the TAVs), diet, nutrition knowledge and attitudes about TAVs, medicinal knowledge and use of TAVs, and child age, weight, and morbidity. The questionnaire was pre-tested with 22 households and revised iteratively so that respondents' understanding and responses to questions were clear and consistent.

The main indicators analyzed are medicinal use of the vegetables, and TAV consumption.

Medicinal use was measured using two survey questions. The first, designed to assess medicinal knowledge, asked, "Can you use any traditional leafy vegetables to treat/prevent any illness?" If the respondent answered yes, data were then collected on which illness was treated with which of the five TAVs. The second question, asked only in the follow-up survey, was, "Has consuming TAVs helped you or someone in your household with any particular illness personally?" Again if the respondent answered affirmatively, data were collected on the illnesses treated and the specific plants used, out of the five TAVs. An indicator of "number of unique illnesses treated with TAVs" was created by counting the number of *unique* illnesses a caretaker listed; if the respondent said "Amaranth and nightshade both are useful for anemia," the response would be coded as only one unique illness. This was done because it was observed that a number of respondents said "all TAVS treat (illness)," a response which did not indicate in-depth medicinal knowledge. It was desirable for the purpose of this study, which sought to classify households based on extent of medicinal knowledge, to differentiate households with generalized knowledge from those who listed specific uses for each of the five TAVs. Binary (yes/no) indicators were also created for whether the household listed a TAV as a treatment for various specific classes of illness (iron-related, malnutrition-related, non-communicable/chronic disease related).

TAV consumption was measured using a 7-day food frequency questionnaire (FFQ) validated by HKI [219]. Respondents were asked how many days per week anyone in the household consumed each of the five TAVs, and if anyone consumed them, how many days the reference child age 2-5 (if present) consumed them. The caretaker was also asked to estimate the amount of each TAV the child consumed on a typical eating occasion, using a standard bowl provided in the survey. From these data, average grams per day that the child consumed were calculated.

Wealth, an important socioeconomic control variable, was measured as a sum of real market values (by site) of 23 durable goods and livestock. Each household was asked how many they owned of each item.

Data entry and cleaning

Data were double-entered in CSPro data entry software [42], using electronic forms that looked identical to the printed survey questionnaire. Frequencies, histograms, and cross-tabulations were used to detect outliers, and implausible data were recoded or removed. In some cases missing data could be found during the data cleaning process; for example if the number of TAVs grown was missing, but in the list of crops grown for the same household, a certain number of TAVs were listed individually as having been grown. Data consistency across years was improved by printing individualized follow-up questionnaires for each household, which included most demographic information obtained at baseline.

4.2.2 Formative research and qualitative methods

A formative research phase informed the creation of the household survey. Interviews and focus group discussions with farmers, extension agents, and program staff, and direct observation were used. These methods were used to gather information about the context, values, and assumptions surrounding production, marketing, knowledge, attitudes, and consumption of TAVs, as well as typical diets, health and nutritional status in the study areas. It was from the formative research that the hypotheses for this study took shape: when discussing health benefits of TAVs, farmers often talked about medicinal uses of the plants, and program staff confirmed that many of the vegetables were traditionally called *dawa*, or “medicine” in Kiswahili. From these observations, the main hypothesis for this study emerged: that households who report greater knowledge of medicinal uses of TAVs will consume more TAVs as food.

Subsequent focus group discussions (FGD) were held in each study site at baseline and follow-up to better understand respondents’ experience producing TAVs, and their consumption decisions and medicinal uses of TAVs. Eight FGDs were held at baseline, 22 more at the beginning of the follow-up survey period (7 women-only, 6 men-only, and 9 mixed gender), and another 10 (all mixed gender) after the follow-up survey was completed to share initial survey results and to elicit farmers’ responses to the data. FGDs were held in a convenient central community location, such as a town or church hall or school, and lasted approximately 30-60 minutes each. FGD respondents were all members of program communities, who expressed voluntary interest in participating in the FGD. Discussion topics included whether participants perceived any health value from consuming TAVs, if so, what, and whether they had heard of certain medicinal practices found in initial survey results. The FGDs also covered other topics unrelated to this study.

4.2.3 Statistical methods

All observations from households with complete survey data for both years were used (169 households in each country; 338 observations per country). Models for each country were run separately because circumstances were unique for each. Pearson chi-square tests of differences in proportions were used to determine significant changes between baseline and follow-up, except where expected cell counts were less than five, in which case Fisher’s exact test statistics were reported. Independent samples t-tests (two-tailed) were used to detect differences in means between baseline and follow-up. Cross sectional analyses were analyzed as mixed effects models using pooled observations from both years of data, controlling for time as a fixed effect, and household ID, district and village as random effects. Longitudinal analyses were carried out as mixed effects models, examining the variables of interest as fixed effects, and controlling for district and village as random effects, where all independent and dependent variables of interest are differenced (time 2-time 1). Panel data has the advantage of controlling for household-level fixed effects, like idiosyncratic tendencies, perceptions, or histories that vary between households but are constant over time. All analyses were carried out in PASW statistical software, version 18.0 [247].

4.3 Results

4.3.1 Description of medicinal uses at baseline

From the survey question eliciting information about *knowledge* of medicinal uses, a list of ailments that could be treated with TAVs was generated. Table 4.2 shows a list of all reported ailments that could be treated with TAVs. Tables 4.3 and 4.4 show the main illnesses treated with each TAV individually.

Responding to the question about knowledge, farmers in Kiambu were much more likely to report medicinal uses for TAVs than farmers in Arusha: almost twice as many Kiambu farmers reported at least one medicinal use (79% in Kiambu vs. 42% in Arusha). The top three illnesses farmers reporting treating with each TAV are shown in Tables 4.5 and 4.6. In both countries, amaranth and nightshade were the TAVs most known for medicinal use, followed by spiderplant. Sweet potato leaf and cowpea leaf were considered medicinal by <10% of households in each country. Farmers in Kiambu also reported a greater number of illnesses that could

Table 4.2: Complete list of ailments for which TAVs were reported to be useful to treat (most common in bold)

Category 1: aches and pains	Category 7: child nutrition
Headache/dizziness	To improve growth
Backache	To improve appetite
Labor pains	**Kwashiorkor/Akoudi/Marasmus**
Toothache	Category 8: micronutrient deficiencies
Category 2: infections	Goitre
Ulcers	Rickets/bone strength
Herpes	**Anemia/Blood/Fatigue**
Wounds	**Eye problems/Night blindness**
Skin infection/Rash/Scabies/Ringworm	Geophagia/pica (*safura*)
Ear problems	Scurvy
Tonsillitis	Category 9: non-communicable diseases
Category 3: illnesses with fever	Reduce fat/lose weight
Fever	**Diabetes**
Measles/Mumps	**Joints/Arthritis/Gout**
Malaria	**High blood pressure**
Yellow fever	Heart disease
Typhoid	Heartburn
Influenza	Stress
Category 4: GI-tract problems	Cancer
Constipation/digestion	Liver problem
Stomach Ache	Kidney problem
Diarrhea/*Orianyanja/Mbaha*	Category 10: unlikely uses
Amoeba	Memory loss
Worms	Hiccups
Category 5: Respiratory problems	Baldness
Respiratory Infection/TB	Impotence
Allergies/Asthma	Category 11: in general
Whooping cough (*kifaduro*)	Lack of vitamins
Category 6: debilitating viruses	Immune Booster
HIV/AIDS	
Polio	

be treated with each vegetable see Table 4.3). Total citations for each vegetable is a summary indicator of the number of households reporting at least one medicinal use for that plant multiplied by the average number of uses reported for that plant per household.

Table 4.3: Baseline knowledge of medicinal uses: Top three uses reported for each plant, Kiambu.

Kiambu (n=169)					
	Amaranth	**Nightshade**	**Spiderplant**	**Sweet potato leaf**	**Cowpea leaf**
Illness 1 (n who said TAV can treat it)	Anemia /fatigue (19)	Stomachache (39)	Diabetes (21)	Diabetes (6)	Diabetes (7)
Illness 2 (n who said TAV can treat it)	High blood pressure (17)	Diabetes (24)	Stomachache (15)	High blood pressure (6)	High blood pressure (5)
Illness 3 (n who said TAV can treat it)	Diabetes (16)	High blood pressure (23)	High blood pressure (15)		
Number of households listing any medicinal use	73 (43%)	107 (63%)	67 (40%)	13 (8%)	15 (9%)
Total unique medicinal uses	25	30	26	14	16
Total citations**	116	173	111	31	33

**Total citations include multiple uses of the same plant if household lists more than one use.

In Kenya, nightshade was the most popular medicinal TAV, with nearly 2/3 of the total sample reporting the possibility of using it to prevent or treat disease. Spiderplant and amaranth were also often thought of as medicinal treatments, with ≥40% of households citing those TAVs to treat disease. Diabetes and high blood pressure were the two ailments that were reported for all of the TAVs. People reported spiderplant and nightshade (the more bitter vegetables) as treatments for diabetes more often than amaranth. The most common ailment treated with amaranth was anemia. Nightshade seemed to be a very popular cure for stomach ache, with nearly a quarter of the Kiambu sample using it as a stomach ache

Table 4.4: Baseline knowledge of medicinal uses: Top three uses reported for each plant, Arusha.

Arusha (n=169)					
	Amaranth	**Nightshade**	**Spiderplant**	**Sweet potato leaf**	**Cowpea leaf**
Illness 1 (n who said TAV can treat it)	Eyes/night blindness (17)	Skin infection/ rash (12)	Anemia/ fatigue (5)*	Anemia/ fatigue (6)*	Anemia/ fatigue (5)*
Illness 2 (n who said TAV can treat it)	Anemia/ fatigue (8)*	Eyes/night blindness (10)	Eyes/night blindness (5)	Eyes/night blindness (5)	Eyes/night blindness (4)
Illness 3 (n who said TAV can treat it)	Marasmus/ Kwashiorkor (8)	Anemia/ fatigue (5)	Stomachache (3)		
Number of households listing any medicinal use	38 (23%)	35 (21%)	17 (10%)	13 (8%)	7 (4%)
Total unique medicinal uses	14	10	10	7	5
Total citations**	49	42	22	18	12

*In addition to the number here, 1 person noted each of these TAVs as a treatment for pica. **Total citations include multiple uses of the same plant if household lists more than one use.

treatment.

As noted, few households in Kiambu considered sweet potato leaf and cowpea leaf medicinal. Although the main diseases treated with sweet potato and cowpea leaves were diabetes and high blood pressure, it is not a reflection of knowledge specific to those plants; all 6 respondents with those responses said "all of the [five] TAVs prevent/treat diabetes and high blood pressure." This may reflect popular promotional and medical advice in Kenya, to eat traditional vegetables in general to treat/prevent NCDs; diabetes is the most salient.

In Arusha, amaranth and nightshade were both reported as medicinal by >20%

Table 4.5: Actual medicinal uses experienced by the household: Top three uses for each plant, Kiambu.

Kiambu (n=169)					
	Amaranth	**Nightshade**	**Spiderplant**	**Sweet potato leaf**	**Cowpea leaf**
Illness 1 (n who used TAV to treat it)	Stomachache (8)	Stomachache (11)	Diabetes (3)	None	Diabetes (1)
Illness 2 (n who used TAV to treat it)	Diabetes (4)	Diabetes (4)	Stomachache (3)		Stomachache (1)
Illness 3 (n who used TAV to treat it)	Anemia/ fatigue (3)	Anemia/ fatigue (2)			
Number of households listing any medicinal use	23 (14%)	23 (14%)	8 (5%)	0	2 (1%)
Total unique medicinal uses	10	9	4	0	2
Total citations	25	25	10	0	2

of respondents. The two diseases that could be prevented/treated using all five TAVs were anemia, and eye problems including night blindness. (Many of the reports of medicinal use were not specific enough to determine whether the respondent was talking about night blindness, clouded vision, or other eye problems; a few people (5) specifically mentioned night blindness.)

Responding to the question about *actual use*, many fewer households reported actually having used TAVs to treat an ailment in their own household than reported knowledge of medicinal use. Tables 4.5 and 4.6 show the top three actual uses by country and by TAV. The percentage of households who used TAVs as medicine was more congruent with the percentage who knew a medicinal use in Arusha (42% knew, 23% used) than in Kiambu (79% knew, 19% used).

Table 4.6: Actual medicinal uses experienced by the household: Top three uses for each plant, Arusha.

Arusha (n=169)					
	Amaranth	**Nightshade**	**Spiderplant**	**Sweet potato leaf**	**Cowpea leaf**
Illness 1 (n who used TAV to treat it)	Anemia/ fatigue (13)	Skin infection/ rash (5)	Stomachache (3)	Anemia/ fatigue (6)	None
Illness 2 (n who used TAV to treat it)	Headache/ dizziness (4)	Stomachache (4)			
Illness 3 (n who used TAV to treat it)	Eyes/night blindness (3)				
Number of households listing any medicinal use	29 (17%)	14 (8%)	8 (5%)	9 (5%)	0
Total unique medicinal uses	10	5	6	3	0
Total citations	33	14	8	9	0

In Kiambu, only four out of the five TAVs were used as medicine, excluding sweet potato leaf. That is not a surprising finding, since almost no one in Kiambu consumed sweet potato leaves (2% of households). The most common uses of TAVs were prevention/treatment of stomach ache, followed by diabetes, each of which was treated with all four medicinally-used TAVs. Anemia was also treated with both amaranth and nightshade. Incidentally, these were the illnesses most people talked about in the focus group discussions.

In Arusha, the most common disease-treatment combination was using amaranth to treat anemia; amaranth was also used to treat headache/dizziness (which could possibly be another way to describe anemia, but which could also result from other causes). Sweet potato leaf, consumed much more often in Arusha than

Kiambu, was also used to treat anemia. Both nightshade and spiderplant were used to treat stomach ache. Amaranth was used for treating eye problems, though again, it is hard to ascribe the ailment definitively to vitamin A deficiency.

There was some harmony between TAV uses in Kiambu and Arusha, as TAVs were used to treat both stomach ache and anemia in both countries. While the veracity of the reported medicinal uses has not been scientifically tested, the fact that TAVs are used for the same maladies in two very different locations increases the chance that the efficacy is genuine [20]. In the case of stomach ache, the physical qualities of the leaves may be easier to digest than most dark green leafy vegetables. (Farmers often described the leaves as "soft.") They may also contain antimicrobial phytochemicals - a testable hypothesis, since plants that ward off pests well generally are rich in bioactive compounds. The high iron content of the leaves is very likely to have provided enough iron to treat anemia, if sufficient quantities were consumed.

It is interesting that a number of people in Kiambu have personal experience using TAVs to treat diabetes, while no one in Arusha used TAVs to treat diabetes. This could reflect promotions of TAVs as a healthy part of diets for diabetics, but it also indicates that diabetes exists in Kiambu. (The fact that so many farmers there talked about diabetes showed that it is a health concern.) Current health data are not available, but it seems quite certain based on personal interviews with local health staff and casual observation of more obesity in Kiambu than Arusha, that diabetes is much more prevalent in Kiambu.

4.3.2 TAV consumption at baseline

Table 4.7 shows the percent of households consuming any TAVs at baseline, percent consuming each individual TAV, the mean number of days TAVs were consumed, and the mean grams per day preschool-age children consumed of TAVs.

Table 4.7: TAV consumption at baseline

	Kiambu	**Arusha**
	n=169	n=169
% who consumed any TAV	64.5	88.8
Mean days TAVs were consumed in the household	2.0	3.5
Mean amount that was consumed by children age 2-5 years	18.5	59.6
% who consumed amaranth	55.6	74.0
% who consumed nightshade	50.3	56.8
% who consumed spider plant	14.2	10.1
% who consumed sweet potato leaf	2.4	26.0
% who consumed cowpea leaf	2.4	30.8

4.3.3 Cross-sectional associations between medicinal knowledge and consumption

The relationship between medicinal knowledge and consumption was assessed cross-sectionally. Both years of data were pooled and analyzed simultaneously in a mixed effects model, controlling for district, village, and household ID as random effects, to account for non-independence of observations. Wealth and age of household head were included in all models as possible confounders. Year was included in all models to test whether there was a time trend in TAV consumption. The interaction of each term with program group was tested because sampling was based on program participation. Where interactions were insignificant at the $p<0.05$ level, they were dropped from the model.

The only significant interaction was between age and program group. The interaction is shown graphically below for Arusha (Figure 4.1). For the comparison group, TAV consumption was positively correlated with age of the household head, but for the program group, adults of all ages ate TAVs at a similar frequency.

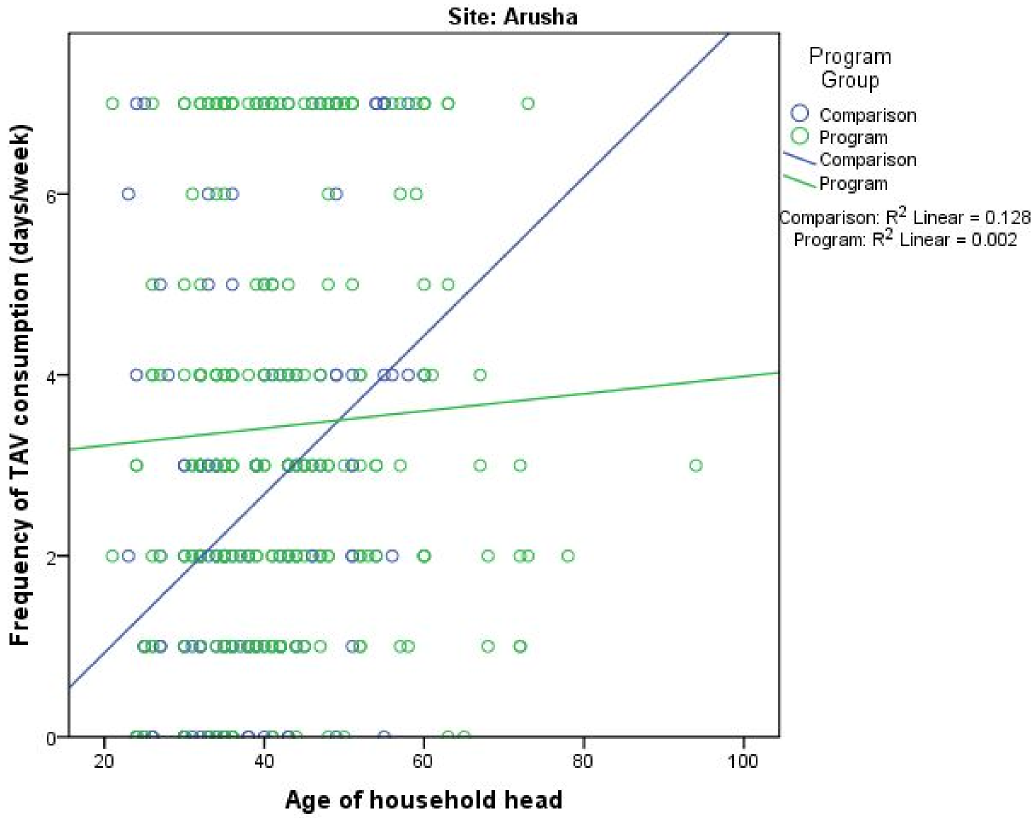


Figure 4.1: Interaction between age and program group on TAV consumption, Arusha

1. Does the number of illnesses the households reports TAVs can cure predict frequency of consumption?

For each additional unique illness a caretaker reported could be treated with TAVs, the household consumed TAVs 0.23 days more per week in Kiambu (p=0.015), and 0.25 days more per week in Arusha (p=0.043) (Table 4.8).

Table 4.8: Frequency of TAV consumption (days consumed/week) based on medicinal knowledge and other covariates

	Kiambu, Kenya		Arusha, Tanzania	
	n=333		n=331	
	Estimate [S.E.]	p-value	Estimate [S.E.]	p-value
Number of unique illnesses treated with TAVs	0.226 [0.093]	0.015	0.250 [0.123]	0.043
Wealth (log value of assets owned)	0.149 [0.103]	0.149	0.049 [0.084]	0.557
Age of household head (years)	0.002 [0.014]	0.886	-0.001 [0.013]	0.925
Program participation	1.176 [0.940]	0.214	2.935 [1.094]	0.009
Year = follow-up	0.797 [0.171]	<0.001	-0.733 [0.196]	<0.001
(Program group × Age of household head) interaction	-0.003 [0.018]	0.850	-0.053 [0.025]	0.038

Note: Models controlled for the random effects of repeated household ID, village, and district.

2. Is medicinal knowledge specific to malnutrition related to child consumption of TAVs?

Among farmers in Tanzania, knowledge that traditional vegetables can be used to treat or prevent diseases related to malnutrition (anemia, scurvy, kwashiorkor, night blindness) was associated with feeding more traditional vegetables to children under age five (15g more on average, p=0.045). The relationship between medicinal knowledge of TAVs as treatment for a malnutrition-related illness was almost entirely explained by knowledge about the use of TAVs to treat iron-related illness. When the variable tested was replaced with "household reported that TAVs can treat a disease related to iron," the new variable was significant (p=0.026) with a large parameter estimate (20.676). When the malnutrition binary variable was used excluding knowledge of use for iron-related illness, the variable was no longer significant (p=0.583).

The same relationships were not seen in Kiambu, where malnutrition-related medicinal use of TAVs was much less frequently reported.

Table 4.9: Dependent variable: Child consumption of TAVs (grams/day)

	Kiambu, Kenya		Arusha, Tanzania	
	n=170		n=255	
	Estimate [S.E.]	p-value	Estimate [S.E.]	p-value
Household reported that TAVs can treat a disease related to malnutrition (ref=no)	3.198 [9.349]	0.733	14.876 [7.399]	0.045
Wealth (log value of assets owned)	0.187 [3.070]	0.952	0.847 [2.588]	0.744
Age of household head (years)	-0.141 [0.328]	0.668	0.265 [0.394]	0.503
Household size	1.536 [2.524]	0.544	-3.042 [1.495]	0.043
Age of child (years)	-0.539 [0.287]	0.064	-0.205 [0.273]	0.455
Number of days child sick in 2 wks prior to survey	-0.057 [1.109]	0.959	-0.516 [0.847]	0.543
Mother's education (years)	-1.666 [1.291]	0.200	-1.325 [1.488]	0.375
Program participation	-15.685 [8.096]	0.057	21.378 [9.946]	0.075
Year = follow-up	18.066 [7.132]	0.012	-13.771 [7.083]	0.053

Note: Models controlled for the random effects of repeated household ID, village, and district.

3. Is medicinal knowledge specific to non-communicable diseases related to household consumption of TAVs?

More farmers in Kenya reported the utility of TAVs to treat or prevent chronic diseases compared to Tanzanian farmers, which may indicate increased salience of medicinal uses according to higher local prevalence of health issues; however knowledge about medicinal use for chronic diseases was not related to TAV consumption frequency ($p>0.1$ in each country). The lack of association may have occurred because there is less intrinsic motivation to consume TAVs to prevent or treat chronic disease if individuals do not perceive that they are at risk for those diseases. Since diabetes and heart disease have recently started to increase in prevalence, farmer households may not be accustomed to eating foods to prevent those diseases.

4. Does medicinal knowledge (number of unique illnesses household reports TAVs can cure) correlate with planting TAVs?

If the previously discussed models control for production, observed correlations between medicinal knowledge and consumption are attenuated or lost. Production could be on a hypothesized causal pathway that looks like this:
medicinal knowledge ($\rightarrow$ production) $\rightarrow$ consumption

As shown in Table 4.10, indeed there is evidence for that particular causal pathway. Among farmers in both countries, medicinal knowledge was highly significantly associated with planting TAVs.

4.3.4 Change in medicinal knowledge between baseline and follow-up

Initially, it was expected that medicinal knowledge would not change over the year-long period between surveys, because medicinal uses are often traditional, based on experience and culture, and slow to shift. However, in light of qualitative evidence that farmers were hearing information about medicinal uses from doctors and the media, and/or perceiving medicinal messages from the program promotion

Table 4.10: Dependent variable: Number of TAVs planted

	Kiambu, Kenya		Arusha, Tanzania	
	n=333		n=331	
	Estimate [S.E.]	p-value	Estimate [S.E.]	p-value
Number of unique illnesses treated with TAVs	0.229 [0.055]	<0.001	0.250 [0.071]	0.001
Wealth (log value of assets owned)	0.110 [0.063]	0.079	0.005 [0.051]	0.914
Land access (acres)	-0.007 [0.040]	0.865	-0.024 [0.016]	0.142
Age of household head (years)	-0.015 [0.009]	0.075	0.002 [0.007]	0.833
Program participation	2.338 [0.581]	<0.001	0.589 [0.566]	0.300
Year = follow-up	0.050 [0.101]	0.622	0.466 [0.117]	<0.001
(Program group × Age of household head) interaction	-0.022 [0.011]	0.048	0.001 [0.014]	0.962

Note: Models controlled for the random effects of repeated household ID, village, and district.

of TAVs focused on their iron and vitamin A content, change in reported medicinal uses was examined. Categories of medicinal uses were chosen based on relevance to the program and secular promotions - knowledge that might be more likely to change.

As seen in Table 4.11, in Tanzania, the percentage of respondents reporting usefulness of TAVs to treat anemia increased greatly (22 percentage points). The increase was significant among both program participants and non-participants (29 percentage points and 13.2 percentage points, respectively). These increases explained most of the increases in “disease related to poverty” and “disease related to undernutrition” as well, since anemia was part of those categories; they were no longer significant when anemia excluded.

In Kenya, the percentage of non-participants reporting usefulness of TAVs to

Table 4.11: Percent of respondents reporting that TAVs can be used to treat the following conditions, at baseline and at follow-up.

	Kenya			Tanzania		
Reported that TAVs can treat:	B	F	p	B	F	p
anemia or geophagia	16.6	11.8	0.213	6.5	28.4	<0.001
eye problems or boost immunity	1.2	0	0.499	12.4	12.4	1
non-communicable disease (a)	33.7	39.6	0.259	1.8	1.8	1
disease related to poverty (b)	31.4	16.6	0.001	14.2	42.6	<0.001*
disease related to undernutrition (c)	19.5	11.8	0.052	21.9	40.8	<0.001*
AMONG PROGRAM PARTICIPANTS						
	Kenya			Tanzania		
Reported that TAVs can treat:	B	F	p	B	F	p
anemia or geophagia	19.6	10.9	0.101	5.4	34.4	<0.001
eye problems or boost immunity	1.1	0	1	15.1	14	0.835
non-communicable disease (a)	47.8	46.7	0.883	1.1	2.2	0.623
disease related to poverty (b)	40.2	15.2	<0.001	14	45.2	<0.001*
disease related to undernutrition (c)	22.8	10.9	0.030	24.7	44.1	0.005*
AMONG NON-PARTICIPANTS						
	Kenya			Tanzania		
Reported that TAVs can treat:	B	F	p	B	F	p
anemia or geophagia	13	13	1	7.9	21.1	0.021
eye problems or boost immunity	1.3	0	1	9.2	10.5	0.786
non-communicable disease (a)	16.9	31.2	0.038	2.6	1.3	1
disease related to poverty (b)	20.8	18.2	0.684	14.5	39.5	0.001*
disease related to undernutrition (c)	15.6	13	0.645	18.4	36.8	0.011*

"B" = Baseline, "F" = Follow-up. (a) high blood pressure, diabetes, joint problems, cancer, heart disease. (b) anemia, malaria, diarrhea, amoeba, worms, ARI, kwashiorkor, marasmus, appetite, goiter, rickets. (c) anemia, eye problems, bones, scurvy, kwashiorkor, marasmus. *In Tanzania, the significant change in the last two categories is almost entirely due to increase in awareness about anemia - same as the first category.

treat non-communicable diseases (NCDs) increased 14.3 percentage points, which was significant. The fact that the increase was among non-participants may reflect general promotion of TAVs for NCDs from radio and TV talk shows as well as clinicians. More participants than non-participants were already reporting usefulness of TAVs for NCDs at baseline (48% of participants vs. 17% of non-participants). Among participants, reports of ability to use TAVs for diseases related to poverty and undernutrition significantly decreased. Much of the decrease in uses for poverty-related illness was due to fewer people reporting usefulness to treat respiratory infections specifically. Reasons for the decrease may be that there were fewer colds going around in the second survey year (so the disease was less salient), or it could have to do with enumerator technique in probing, although the probability of that is low since several Kiambu enumerators were the same in years 1 and 2. As for the decline in diseases related to undernutrition, no one malady stood out as having changed between baseline and follow-up. It is possible that undernutrition was becoming less salient of an issue overall compared to overnutrition and NCDs. There was a limited space on the questionnaire to list illnesses treated (only three spaces) so salience is important in reporting medicinal uses: the first diseases to come to mind were the ones recorded, even if there were many diseases that the household knew could be treated with TAVs. In short, the rising salience of NCDs might have "pushed out" undernutrition.

Although the data are not presented, there were declines in every category from baseline to follow-up. Overall, however, total number of medicinal uses cited was slightly higher than baseline, so increased respondent fatigue in answering the questionnaire cannot explain the decrease; rather, it seems households were reporting a greater diversity of cures in the second survey round.

4.3.5 Longitudinal relationship of change in medicinal knowledge and change in TAV consumption

Tables 4.12 and 4.13 show that controlling for other factors hypothesized to change over time within households, increase in medicinal knowledge is associated with increase in TAV consumption in both countries. In Kiambu, knowledge gained of one new additional illness that can be treated with TAVs was associated with a 0.16-day increase per week in TAV consumption ($p=0.048$). In Arusha, the variable tested was knowledge of iron-related illness, because as shown above, that was the variable which changed between baseline and follow-up. Gaining knowledge that TAVs could treat iron-related illness was associated with a 1.26-day increase per week in TAV consumption ($p<0.001$), and a 26.4 gram per day increase in the amount of TAVs fed to preschool-age children. No relationship between medicinal knowledge and child consumption was seen in Kiambu, partly because of a much smaller sample size, and partly because many of the illnesses respondents listed in Kiambu (diabetes, high blood pressure) would not affect children.

4.4 Epistemological discussion

In descriptions of "medicinal knowledge," this paper uses an epistemic relativist perspective, which assumes our knowledge of reality is always questionable, and defines knowledge as what is accepted as real by an individual or culture at a given time. This contrasts with an epistemic realist perspective, which assumes that we can know the truth about the world with certainty and therefore might classify medicinal perceptions from any culture as "beliefs." The use of a relativist perspective sets the tone for discussions of "knowledge" which have not, in most cases, been tested by modern science.

Table 4.12: Change in consumption based on changes in production, knowledge and attitudes, Kiambu, Kenya.

	Δ Frequency		Δ Amount (g/day)	
	n=154		n=77	
	Est. [S.E.]	p	Est. [S.E.]	p
Δ production (# TAVs cultivated)	0.246 [0.117]	0.038	-0.595 [2.504]	0.813
Δ attitude score	0.083 [0.089]	0.353	0.684 [1.998]	0.733
Δ micronutrient knowledge score	0.155 [0.135]	0.252	-3.295 [3.646]	0.369
Δ medicinal knowledge (# treatments known)	0.247 [0.124]	0.048	0.762 [2.646]	0.774
Δ wealth (value of assets owned)	-0.006 [0.014]	0.649	0.117 [0.296]	0.695
Baseline wealth (log value of assets owned)	-0.071 [0.145]	0.624	-1.036 [2.915]	0.723
Household head age (years)	0.003 [0.012]	0.827	0.661 [0.290]	0.821
Program participation	1.088 [0.352]	0.002	20.901 [8.741]	0.020
Δ Household size	-	-	-2.590 [4.601]	0.575
Δ days child sick in last 2 weeks	-	-	-0.267 [0.928]	0.774
Baseline TAV consumption (days/week)	-0.554 [0.088]	<0.001	-0.820 [0.162]	<0.001

All variables listed were treated as fixed effects; analyses also controlled for district and village as random effects.

The source of medicinal knowledge in the study populations is important for several reasons: first, to understand baseline knowledge so that nutrition-focused marketing messages could be better-adapted to existing knowledge, second, to determine whether recent promotional information might be responsible for changing beliefs or knowledge about medicinal uses of TAVs, and third, to document

Table 4.13: Change in consumption based on changes in production, knowledge and attitudes, Arusha, Tanzania.

	Δ Frequency		Δ Amount (g/day)	
	n=154		n=116	
	Est. [S.E.]	p	Est. [S.E.]	p
Δ production (# TAVs cultivated)	0.076 [0.104]	0.468	0.441 [3.296]	0.894
Δ attitude score	0.222 [0.083]	0.008	4.108 [2.314]	0.079
Δ micronutrient knowledge score	0.020 [0.105]	0.851	-0.292 [3.207]	0.928
Δ medicinal knowledge (TAVs used for iron-related ailment)	1.264 [0.345]	<0.001	26.368 [10.758]	0.016
Δ wealth (value of assets owned)	0.016 [0.016]	0.307	0.582 [0.485]	0.233
Baseline wealth (log value of assets owned)	-0.163 [0.104]	0.119	-1.455 [3.109]	0.641
Household head age (years)	0.023 [0.014]	0.091	0.554 [0.430]	0.201
Program participation	0.622 [0.302]	0.041	17.745 [10.867]	0.182
Δ Household size	-	-	-4.514 [3.553]	0.207
Δ days child sick in last 2 weeks	-	-	-0.237 [0.899]	0.793
Baseline TAV consumption (days/week)	-0.754 [0.067]	<0.001	-0.886 [0.078]	<0.001

All variables listed were treated as fixed effects; analyses also controlled for district and village as random effects.

genuinely indigenous uses of the plants in order to (a) catalogue ethnobotanical knowledge and (b) generate hypotheses about plant bioactivity that can be tested in the laboratory, which could benefit other people.

The source of knowledge, however, was often a difficult question for people to answer, particularly for knowledge that they may have had for a long time. This points to the hypothesis that if people can definitively report/identify a source, then knowledge is more likely to be recent, and if they cannot, the knowledge is more likely to be old or perhaps indigenous.

Focus group discussions provided a good indication of where knowledge might have come from. In Kiambu, medicinal knowledge for the majority of the (Kikuyu) population seemed to be coming from doctors, radio, TV, and the marketplace. That is, it was mostly not indigenous. Many FGD participants reported that they heard information from doctors, saying "Local herbalists/doctors - they say to eat TAVs to avoid the pharmacy." There was also a popular television show on which a doctor talked about the health benefits of TAVs. Although most Kiambu farmers did not have a television, they knew of the doctor. Much of the advice they reported hearing had to do with diabetes, blood pressure, cancer, and other chronic diseases. In contrast, the stomach ache treatment was more likely than the rest to be indigenous knowledge, because many people talked about it in terms of personal daily experience, rather than something they heard from a doctor or herbalist. People talked about nightshade leaves being "soft" - easy to digest - so they could be eaten more often than kales with fewer ill effects.

Proximity to Nairobi, the tribal melting pot of the nation, certainly would have facilitated spread of traditions from one Kenyan group to another. Luo, native to Western Kenya, have strong traditions of using wild leaves as medicine and sell TAVs in the Nairobi markets as *dawa* - medicine. Modern medical ailments and advice appear to be mixed with Luo and Luhya, and perhaps other, traditional practices.

The medicinal knowledge seemed to be a source of enthusiasm among the farmers - they seem excited that the former weeds in their farm might be useful in such varied and interesting ways, and also that they might be able to profit from it. The profit/marketing motive may have driven many Kikuyu farmers to spread the new about of TAVs to their neighbors. One man said “My grandfather used to sell these as medicine for a big profit - why not us?” While the Kikuyu are known in Kenya for being entrepreneurial, it also seemed that not only money was motivating them; they also felt a sense of pride and believed in what they were trying to sell. This impression was gained from observations in focus group discussions, where on numerous occasions farmers said they themselves are the ones telling their neighbors about how healthy TAVs are, either in terms of nutrients or testimonials of diseases cured, or both.

In Arusha, in contrast, the vegetables are not new. People talked about knowledge from doctors and from the TF Project when they were discussing anemia; but for most of the other diseases, it was difficult to get a clear picture of exactly where they learned the information they volunteered . That could mean that the source of knowledge was indigenous - that the farmers had learned the medicinal uses of TAVs so long ago they can’t pinpoint when or where they learned it; it was just “known,” ingrained in the culture. They described specific techniques to prepare and use the TAVs to treat eye problems and problems related to malnutrition (using local indigenous names for diseases associated with malnutrition - for example, several different names for different kinds of diarrhea), and no one said they learned those techniques from an outside source. The Arusha farmers were very clear, however, that the uses of TAVs for diabetes and blood pressure were not indigenous - and also, very few people reported those uses (about 2% in both baseline and follow-up).

The knowledge changes observed in Kiambu related to NCDs were probably not related to the program, because messages specific to NCD prevention were not a focus of the promotion efforts; rather, they were probably due to other simlutaneously-occurring promotions from Nairobi. In Arusha, change in knowledge was related to program messages about iron content of TAVs. Information about anemia prevention seemed to catch on quickly there - more so than in Kiambu. This could be related to greater indigenous knowledge of TAVs as a treatment for anemia in Arusha.

The illnesses people treated with TAVs may also say something about the prevalence of illness. In Kiambu, about three times as many people used plants for diabetes as for anemia, but in Arusha, it was the opposite.

4.5 Discussion and Conclusions

This study shows evidence that among people who consume traditional leafy vegetables, those with greater medicinal knowledge about the vegetables consumed more of them. In Tanzania, the medicinal knowledge was likely mostly indigenous, and in Central Kenya, the medicinal knowledge was largely introduced from other tribes and modern media. In both situations, increased medicinal knowledge was associated with greater consumption cross-sectionally and over time. The consistency of the association, despite the different ways the knowledge came about, shows evidence that both indigenous knowledge and ethnobotanical knowledge learned from non-indigenous sources can have profound effects on eating choices for health.

Previous research has shown a link between local ethnobotanical knowledge and nutritional status, but no research to date has elucidated the so-called "black box" between traditional ethnobotanical knowledge and nutrition [166]. This study shows a possible mechanism: that medicinal knowledge related to vegetables is positively correlated with consumption of traditional vegetables, which itself could reasonably be associated with micronutrient and calorie intakes. This study only collected one nutritional status indicator (weight-for-age), and did not have a large enough sample size to detect a difference in weight-for-age based on vegetable consumption. However this study builds on previous literature by showing evidence for a new link between ethnobotanical knowledge and nutrition: dietary intake. Many people assume that ethnobotanical knowledge has to do only with medicine for treatment purposes only. "Herbal remedies" is a term sometimes used synonymously with ethnobotany. While the overarching paradigm of ethnobotany is certainly medicine, this study shows that among those who are actively using the knowledge, healing and medicinal use of plants is interpreted more broadly than as *curative* remedies. Rather, healing and medicinal use of plants take the form of every day food choices, aimed at improving the health of household members, particularly children.

Ethnobotanical or local medicinal knowledge is important to respect and nuture not only because of the intrinsic value of knowledge and out of the principle of respecting autonomy among all people, but also because it may be a practical tool in maintaining good nutritional practices that already exist. In communities well into the nutrition transition, there is great practical value for nutrition in sustaining cultural diversity which allows maintenance of traditional medicinal knowledge, and biodiversity that allows traditional medicinal knowledge to be used, combined with increased communication and infrastructure that allows sharing of traditional knowledge and foods. By providing knowledge and foods that can add nutritional value to the diets of both undernourished and overnourished people, biocultural diversity can mitigate both sides of the double burden of malnutrition.

To discover more about the association between nutrition and ethnobotany, future research should aim to link all steps in the hypothesized chain from ethnobotanical knowledge, to consumption, to nutritional status (Figure 4.2). This paper shows links between knowledge and consumption, and other work has shown links between knowledge and nutritional status [166], and between consumption and nutritional status [50, 147], but no research has shown the whole pathway. This is an understudied area and no published studies even attempt to show all three links, so it is an area ripe for further exploration. Particularly at a time when biocultural diversity is being lost rapidly due to modernizing forces that fail to protect it, and that simultaneously encourage dietary simplification, the need for future research in this area is great.

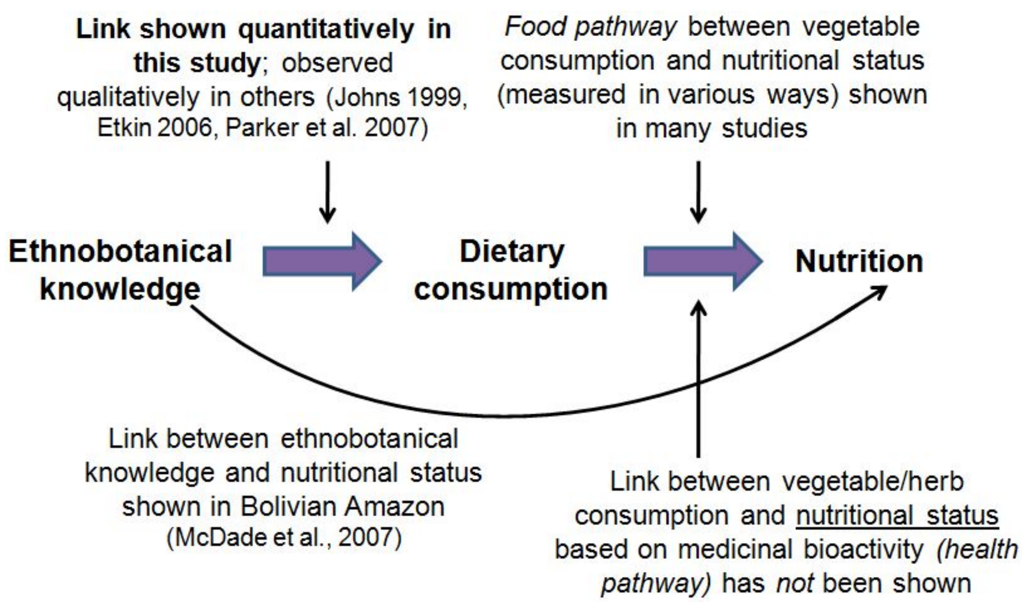


Figure 4.2: Possible causal chain from ethnobotanical knowledge to nutrition

An inherent design limitation in this study is that cross-sectional analyses, particularly of variables related to individual choice, are likely to suffer from confounding from omitted, unmeasurable variables having to do with idiosyncratic choice. Cross-sectional results reveal correlation, rather than causation; links between medicinal knowledge and consumption could be explained three ways:

1. Knowing medicinal uses might cause increased consumption.
2. Eating the vegetables might cause farmers to seek information about health benefits.
3. People who are more traditional might know more traditional medicines *and* eat more traditional foods. Models attempted to control for this by including age of household head as a proxy for traditional orientation.

The analyses were done cross-sectionally, however, because of the slow time-frame over which medicinal knowledge generally changes, which makes longitudinal analyses difficult. Among variables that showed some change over time, the longitudinal analysis bore out the positive, significant relationship between medicinal knowledge and consumption in both Kenya and Tanzania. Because of the consistency between cross-sectional and longitudinal results, the confidence in the validity of cross-sectional results is improved.

The implications of the probable link between medicinal knowledge and dietary consumption are great. The lack of perceived boundary between food and medicine challenges the traditional separation of the determinants of nutrition into food, health, and care [268]. Food and health are sometimes, but not always, separate entities in practice. This study illustrates clearly a case in which people consume certain foods as both food and medicine, which may have to do with nutrition through both pathways: providing nutrients as food, and preventing or treating disease as medicine. Some of the "medicinal" uses are nutrient-related, such as preventing anemia. Others, however, are not nutrient-related, such as use for stomach ache or intestinal worms. Medicinal uses of plants, including food plants, is an adaptive strategy for fitness (nutritional status) through providing both food-related and health/disease-related benefits. Figure 4.3 shows the immediate and underlying causes of malnutrition, but with a connection between food and health, since food can relate both to nutrient intake and to prevention or treatment of disease. Not all foods are medicines and not all medicines are foods, but there is certainly some shared space.

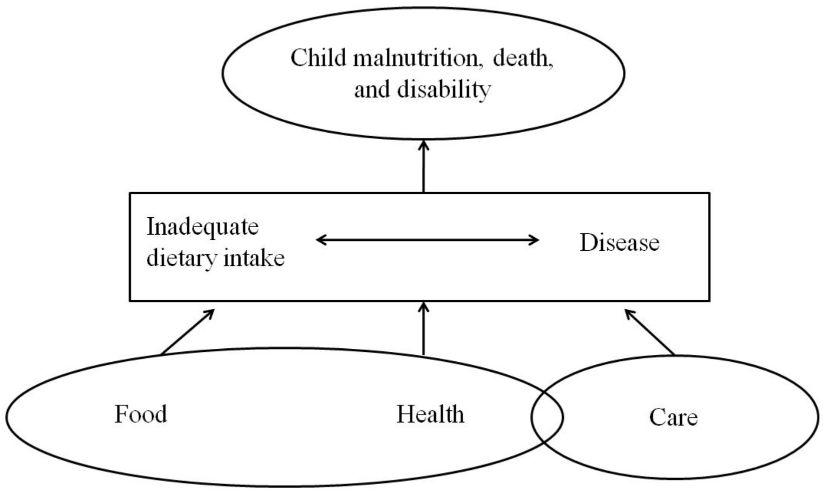


Figure 4.3: Alternative view of the UNICEF framework on the determinants of undernutrition

The implications for nutrition practice are perhaps equally as great. Implementing interventions based on knowledge without any understanding of knowledge already contained in communities is inefficient at best, and harmful at worst. Subtle or overt denigration of traditional knowledge on the part of public health or agricultural interventions can cause people to become ashamed of their practices, and can hasten the rejection of heritage and the loss of knowledge. It is not only respectful of people and culturally competent, but may be crucial to public health goals to recognize and support beneficial traditional knowledge.

An awareness of ethnomedicine is important to nutrition and public health, because it can explain some household behavior regarding food intake and health. This is important to understand and work with in nutrition interventions. If people report that local green vegetables are an indigenous medicine for anemia, for example, researchers and practitioners can easily dovetail nutrition information about iron to align with pre-existing knowledge.

Validation of existing knowledge can increase empowerment within communities, which is a much better long-term outcome of interaction with program staff than if targeted individuals leave confused about nutrition information and vaguely feeling that they do not have the tools to handle malnutrition. This concept is related to positive deviance, which rests on the assumption that there are always some tools that already exist within a community to improve health and nutrition [189]. Exploiting them potentially means more than solving the malnutrition problem immediately - it also can influence self-efficacy, self-respect, culture and empowerment long-term.

There are also cases when researchers or practitioners may have good evidence that a particular local practice is harmful. In that case, failing to intervene may be a lost opportunity to avoid harm, but intervening also carries a risk of *causing* harm: the potential implication coming from an outsider that all traditional knowledge should be replaced with modern information. For this reason, it is helpful for researchers and intervention staff to also identify traditional practices which are beneficial, and to underscore those practices while disagreeing with any practices known to be harmful, so that the overall interaction between the intervention staff or research and the community is one of mutual esteem and learning rather than creating a dynamic of one-way information flow.

Inclusion of ethnomedical knowledge in nutrition and public health interventions is important for these reasons:

a. **Communication** - understanding where people are coming from, what they already know, and how they understand health properties of food, informs nutrition behavior change communication. Interventions are more likely to convince people of new information if it relates to pre-existing knowledge and knowledge frameworks.

b. **Empowerment through validation** - if people are convinced they have the wisdom and tools to treat one malady, they may feel greater self-efficacy in other areas of health.

c. **Preservation of knowledge** - knowledge for knowledge's sake

d. **Utility** - possibility to help others elsewhere (many drugs have come from natural cures [262], and functional foods are now gaining importance [285])

e. **Evaluation** - to understand if the intervention is influencing knowledge

For communication and evaluation purposes, the program evaluated here appeared to be consistent with medicinal knowledge in each site, which may have increased understanding and retention of nutrition messages. Program implementation staff were alert to traditional medicinal use of TAVs for anemia and to a lesser extent eye problems in Arusha, and related program messages about iron and vitamin A to pre-existing knowledge about the plants. The messages about iron content may have contributed to an increase in reporting that TAVs could treat anemia in Arusha. In Kiambu, although specific information about medicinal uses appeared to be relatively new, ways of thinking about health benefit appeared to be more traditional: knowledge was often framed in terms of medicinal properties, rather than biochemical nutrient content. For the program to frame messages about micronutrients in medicinal language even more than was done may have been important there.

This is not to say that traditional knowledge of unknown veracity should be *promoted*; rather, it should be regarded respectfully, and should not be reflexively rejected by scientifically-trained outsiders. There are some cases where traditional knowledge conflicts with outside scientific knowledge, many cases where traditional knowledge has not been scientifically tested, and some cases where traditional and modern scientific knowledge agree. For the sake of cultural competency, scientific curiosity, and support of self-efficacy in communities where public health interventions take place, traditional knowledge should be regarded with respect in all cases. Where it conflicts with modern scientific understanding, a respectful dialogue can begin to explore the roots of the beliefs and ways of shifting behaviors so that they better promote health. Where a definitive overlap exists (such as where dark green leafy vegetables are used as medicines for anemia), it is both ethical and useful to acknowledge and build on traditional knowledge in public health interventions.

For the success of interventions, and the inherent and applied value of cultural diversity, incorporating pre-existing medicinal knowledge into nutrition programs is important. Solutions old and new can be applied to the changing landscape of nutritional problems in nations worldwide.

CHAPTER 5

FROM TRADITIONAL VEGETABLES TO NUTRITION? MODELING AN AGRICULTURAL INTERVENTION TO EVALUATE PROGRAM THEORY AND POTENTIAL IMPACT ON DIET AND NUTRITION IN CENTRAL KENYA

5.1 Introduction

A program promoting traditional African vegetables among farmers north of Nairobi, Kenya, has the potential to affect multiple nutrition outcomes among farmer households through multiple pathways. The objective of this paper is to evaluate whether the intervention had any effect on diet and nutrition-related outcomes among smallholder farmers in its first year of implementation. Results are compared not only by program participation, but also by major program outputs, to test whether the program theory of how production and marketing of TAVs would lead to better diets and nutrition is correct. The results can inform future agricultural programs in sub-Saharan Africa to have an increased chance of improving individual and public health nutrition.

5.1.1 The nutrition situation in Kiambu

The nutrition situation among the population of rural farmers surrounding Nairobi, Kenya, is diverse and changing. Undernutrition is commonly considered a defining characteristic of sub-Saharan Africa, which holds true for Kenya as well: Kenya is one of the 36 countries that make up 90% of the global burden of undernutrition [19]. Currently 35.3% of children under age five in Kenya are stunted (-2 z-scores) and 16.1% are underweight (-2 z-scores) [136].[1] These rates have held constant

[1] Undernutrition rates for 2009 are compared to the WHO Child Growth Standards.

since 1990 [270], although the Millennium Development Goal 1 was to halve poverty and hunger, including child underweight, from 1990 levels by 2015. Hidden hunger is a problem as well. In Kenya, an estimated 70% of children under 6 have subclinical vitamin A deficiency and 60% have iron-deficiency anemia [271].

Kiambu is a district just north of Nairobi, with relatively better access to markets and services than much of the nation, and also with favorable agronomic conditions for farming. The majority of the Kiambu population depends on agriculture for their livelihoods, and tea, dairy, and vegetables are major crops produced there. Sitting at 2,000 meters above sea level, the district does not experience severe dry, hot seasons and crops are produced year-round. Current national statistics show that stunting affects 32.4% of children under age five in Central Kenya, which includes Kiambu; 12.1% are underweight [136]. (In Nairobi, which borders Kiambu, 28.5% of children are stunted and 7.9% are underweight.) High rates of stunting even among the wealthier regions of the nation, combined with somewhat low rates of underweight, indicate that stronger attention must be paid to maternal and infant health during the critical window of growth from -9 to 24 months of age. Past that window, for children age 2-5 years, prevention and treatment of disease as well as improved dietary quality, rather than quantity, are the solutions that can best promote optimal child nutrition and growth. Improved dietary quality while avoiding excessive caloric intake is particularly important in situations of high stunting and low underweight, since early undernutrition (reflected in stunting) may predispose children to greater risk of chronic disease [281], which is rising rapidly in Africa.

As is happening in low and middle-income countries around the world, a nutrition transition is occurring in Central Kenya, marked by a shift to a diet high in sugar, fat, refined carbohydrates and processed foods and an increase in overweight, obesity and related chronic disease such as diabetes, hypertension, and cardiovascular disease [58, 204, 206]. Updated data are not available, but using data from the mid-1990s, overweight exceeds underweight among women in both urban and rural areas of Kenya [168]. Between 2000 and 2030, a close to three-fold increase in diabetes and heart disease is predicted in sub-Saharan Africa [296]; these estimates do not take into account urbanization and dietary changes associated with moving to cities. Diabetes presents particular problems and risk because medical treatment is largely unavailable in sub-Saharan Africa, and when it is, it costs half to two-thirds of average yearly income [14]. Given the increasing rates of chronic disease and low life expectancy after contracting them, available evidence suggests that the probability of death from chronic disease is higher in sub-Saharan Africa than in established market economies [276]. Among children, obesity rates in sub-Saharan Africa are only about 5%, but are increasing more rapidly than in any other region of the world [297, 264].

Given the nutrition context of Kiambu, where risk of undernutrition and obesity and chronic disease coexist, a primary nutritional goal would seem to be to improve quality of diets. Even better than doing so merely at household level would perhaps be to institute changes to the food system so that risk of obesity and chronic disease are reduced for the whole population and the next generation.

Dietary diversity is a key recommendation in national and global dietary guidelines [278, 293]. A variety of foods ensures nutrient adequacy, provides a variety of phytochemical and non-nutrient components that promote good health, and reduces overconsumption of certain nutrients such as fats and sugars. Child dietary diversity (food groups) and dietary variety (individual foods) are positively associated with caloric and micronutrient adequacy [251, 134, 99, 255], hemoglobin concentration [17], and child growth [251, 255, 8, 186]. Dietary diversity, and particularly botanical dietary variety, is associated with reduced hypertension and reduced risk of chronic disease such as cancer, cardiovascular disease and diabetes [174, 256, 149, 239, 10, 11, 108, 127, 80].

Nationally, 25% of households in Kenya have poor dietary diversity, classified as consuming less than four out of seven food groups (starchy roots and cereals, pulses, dairy, meat and fish, eggs, fruits, and vegetables) [241]. Both diversity of foods and of food groups need to be supported for optimal household and public health nutrition in Kenya.

Many studies on the effects of horticultural interventions have measured biochemical indicators of nutritional status, dietary intake of micronutrients, and frequency of consumption of specific target foods to assess impact [298, 221, 15]. While such studies are useful in showing an impact of specific foods on specific indicators of nutritional status, their approach does not capture the unique strength of food-based approaches to improved nutrition: their potential for improving diet pattern as a whole.

Focusing only on consumption of promoted crops ignores that dietary diversification is often most efficiently accomplished through increasing real income, especially that controlled by women - which agricultural interventions may do well. As incomes increase, food expenditure increases and purchases diversify [132, 236], which increases dietary diversity [259, 85].

Dietary diversity or variety, however, is not a common indicator for assessing dietary impact. A few studies have assessed program impact using a diversity score of vitamin A-rich foods consumed [9, 95]. A handful have related an agricultural of food-based intervention to overall diet diversity. One showed a significant improvement in household diet diversity among farmers in Honduras who had participated in a year of a rural development program offering credit and technical assistance, compared to non-participants [177]. Another was a descriptive report where diet diversity of households with different types of home gardens were compared to those without gardens in Bangladesh [105]. A third measured change in dietary diversity as a context indicator for a child feeding intervention with ready to use foods [109]. This study relates an agricultural intervention to dietary diversity, an indicator of the factors the intervention is most well-suited to change: household and child diet quality.

5.1.2 Description of the intervention

The Traditional Foods Project was designed and implemented as an income-generating program within the context of the dual burden of malnutrition, and aimed to capitalize on the many attributes of underutilized traditional foods that could potentially make inroads into poverty and malnutrition. The goals of the program were to increase production and marketing of traditional African vegetables (TAVs) among smallholder farmers, and to improve household income and nutrition. It was a three-year program implemented in Kiambu, Kenya and Arusha, Tanzania by the International Potato Center (CIP), the World Vegetable Center Regional Center for Africa (AVRDC-RCA), and Farm Concern International, a Kenyan non-profit organization.

The program had four main components: (1) agronomic training and seed supply; (2) farmer cooperative formation and links to buyers; (3) a nutrition-focused marketing campaign, which used posters, flyers, demonstrations, and television to promote the image of TAVs among consumers, based on their nutritional content; (4) farmer training about the nutritional content of the vegetables.

Five TAVs were chosen for promotion in the TF Project based on their nutritional profile, their existing abundance in the sites' agroecosystems, and their popularity relative to other TAVs, which gave them a higher potential for marketability. All five of the TAVs were dark green leafy vegetables: amaranth (*Amaranthus* spp.), nightshade (*Solanum nigrum, S. scabrum, S. americanum*), African spider plant (*Cleome gynandra*), sweet potato leaves (*Ipomoea batatas*), and cowpea leaves (*Vigna unguiculata*).

TAVs have several attributes which make them an ideal crop for promotion in this context. They are rich in micronutrients, particularly iron and provitamin A [151]. They grow rapidly, in 4-6 weeks, and can be harvested multiple times per planting; this allows them to be a fast income-generator if they can be marketed. In general, they require fewer inputs than exotic varieties, since they are well-adapted to the agroecosystem: amaranth, nightshade, and spiderplant commonly grow as weeds, even in dry seasons. Lack of input requirements results in saved money for farmers on pesticides, fertilizers, and irrigation, although farmers still typically use some inputs if they plant TAVs. TAVs are also traditionally women's crops, so that women may have a chance to control income from them if they are sold. As a cash crop, TAVs are beginning to function as niche crops, particularly near Nairobi due to increased demand for "healthy" and traditional foods to deal with obesity and chronic disease, and thus present a new income-generating opportunity. If farmers grow TAVs and market them to consumers, they are also contributing to a healthy food system, leveraging biological diversity and cultural traditions to increase healthy food offerings in both rural households and urban centers.

Urban consumers' demand in Nairobi stems partly from the fact that this intervention takes place in the context of past and ongoing TAV promotions in Kenya, particularly in Nairobi. Various projects have promoted TAVs in Kenya since the late 1970s, which have gained more partners and become coordinated in the last ten years, now reaching the level of annual promotional parades and possible inclusion of TAVs in national policy. From 2003-2006, Farm Concern International implemented a pilot project connecting Kiambu farmers to Nairobi supermarkets to sell TAVs. The project was highly successful at increasing farmer incomes from TAV production, and appeared to influence consumption among farmers, but did not explicitly test dietary impact. The Traditional Foods Project scales up the pilot project in the same region, and this study evaluates impact on diet.

5.1.3 Objectives

The objective of this study is to show whether an agricultural program promoting production and marketing of traditional African vegetables was related to improved diets among participating smallholder farmer households, and to test each critical step along the program impact pathway to evaluate whether the program theory is sound.

1. To show whether program participation was related to improved quality of diets, as measured by dietary diversity, vegetable consumption, and consumption of vitamin A-rich and iron-rich foods.
2. To show whether program participation was related to overall economic well-being, women's income control, food purchase diversity, and crop diversity, which could contribute to diet quality.
3. To test the program theory that increased production and marketing of TAVs would lead to better diets, through
   - (a) increased production of micronutrient-dense vegetables, facilitating the addition of nutritionally rich vegetables to the diet, and
   - (b) earned income (in the hands of women) and overall economic well-being, facilitating diversified food purchases.

4. To test if diversified diets are related to nutritional status (weight for age) in preschool children in this sample.

5.1.4 Hypotheses

1. Program participation leads to increased dietary diversity, increased vegetable consumption, and increased iron-rich and vitamin A-rich food consumption .
2. Main program outputs (increased TAV production and sale) improve dietary diversity and other dietary indicators.
3. Program participation leads to increased economic well-being, increased women's control of income, diversified food purchases, and diversified crops on-farm.
4. Main program outputs (increased TAV production and sale) increase economic well-being, women's control of income, and diversify food purchases and crop diversity.
5. Overall economic well-being, increased women's control of income, food purchase diversity, and on-farm crop diversity are positively related to diet quality.
6. Dietary diversity is positively correlated with nutritional status of children age 2-5 years in this population.

5.2 Methods

5.2.1 Study design and survey

A baseline survey was done immediately following recruitment of households into the program, and a follow-up survey was administered to the same households one year after baseline. The survey was administered to 181 farmer households at baseline (October, 2007). In the one-year follow-up survey, six percent of households were lost to follow-up , mostly due to moving away. A total of 169 households were interviewed twice.

Sampling frame

Four divisions were included in the study. Prior to the start of the study, program staff had selected four villages for the TAV program implementation, which were located in four different divisions. Program staff reported that the main selection criteria for villages where the program would operate were prior experience producing horticultural crops, agronomic suitability for production, and proximity or access to markets. In keeping with the overall evaluation design, in each district, another village was selected based on similarity to the program village in size, wealth, proximity to markets, average household size, and public services availability. The survey was therefore administered in eight villages: four program villages, and four matched comparison villages. In each program community 25 households were interviewed, and in each comparison community, 20 were interviewed.

Respondent selection

In program villages, households to be interviewed were selected randomly from lists of program participants. In comparison villages, households were randomly selected from village census lists. The initial intent was to interview only households with children age 2-5 years, but this inclusion criterion was subsequently dropped due to many households who were recorded as having young children actually did not have children in that age group. Respondents within the household included three distinct roles: the person mainly responsible for agriculture, the person mainly responsible for TAV production, and the person mainly responsible for taking care of the reference child age 2-5 years (or if there was no child, the person responsible for the majority of the cooking for the household). If a required respondent for a particular questionnaire section was temporarily unavailable, the interviewer made an appointment to return later in the day or week to complete the questionnaire with the appropriate respondent.

Household survey administration

The survey was administered over a period of four weeks, and the follow-up survey was administered exactly one year after the baseline also so that changes seen in agricultural production and TAV use were not due to differences in seasonality. Teams of interviewers administered the questionnaire in Kikuyu, the local language of respondents. During interviewer training, the importance of communicating consistent meaning of each question was emphasized, and role playing, discussion, and practice interviewing ensured that interviewers fully understood each question and agreed on its exact translation. The survey took one to two hours to complete for each household. Each day of the survey, research assistants and the PI reviewed the filled questionnaires, held a de-briefing session with enumerators, and returned any questionnaires with inadvertently missing information for follow-up.

Changes in participation status

The survey recruited households at baseline who intended to participate in the program at its initiation. By the 1-year follow-up, 31% of participants at baseline had stopped participating in the program. They were still interviewed at follow-up to test hypotheses related to program theory, but were grouped separately from consistently active participants in analyses of program effect. Respondents are divided into categories of actual participation: comparison, baseline-only participants (stopped participating before the follow-up), and consistent participants. Baseline-only participants heard many of the messages associated with the program's promotion of TAVs based on nutrition, but may not have received seeds or joined groups to take advantage of the income-generation part of the program. From baseline to follow-up, no comparison households joined the program.

Measurement of constructs

Outcome variables included dietary quality indicators and an indicator of overall change in economic wellbeing. Intermediate indicators included diversity of food purchases, crop diversity, and women's economic decision-making power. Exposure indicators included program participation, TAV production, and TAV marketing. A summary of how each variable was measured is shown in Table 5.1.

Table 5.1: Construct measurement

Construct	**Definition and method**	**Range**
Dietary diversity score (household): HDDS	Count of 12 food groups consumed by anyone in the household in the 24 hours prior to the survey, using a 24-hr recall technique for generating a food list*	0 to 12

Table 5.1 (continued)

Dietary diversity score (individual child age 2-5 years): IDDS	Count of 8 food groups consumed by the child in the 24 hours prior to the survey, using a 24-hr recall technique for generating a food list**	0 to 8
Dietary variety score (household): HDVS	Count of all unique food items consumed in the household in the 24 hours prior to the survey, using a 24-hr recall technique	0 to ∞
Dietary variety score (individual child age 2-5 years): IDVS	Count of all unique food items the child consumed in the 24 hours prior to the survey, using a 24-hr recall technique	0 to ∞
Number of fruits and vegetables consumed	Count of number of fruits and vegetables consumed in the household in the 24 hours prior to the survey, using a 24-hr recall technique	0 to ∞
Number of vitamin A-rich foods consumed	Number of times food items containing $\geq 100\mu$g RAE/100g were consumed in the last week, using HKI 7-day FFQ [219]†	0 to 70
Number of iron-rich foods consumed	Number of times food items containing $\geq$ 1mg iron per 100g were consumed in the last week, using HKI 7-day FFQ [219]†	0 to 70
Change in economic wellbeing	Response to how overall economic situation has changed in the last year	0 (no change), 1 (improved), -1 (worsened)
Baseline wealth	Sum of real market values of 23 durable goods and livestock	0 to ∞
Women's purchasing decision-making power	Addition of responses to four questions: who decides about major new purchases & food purchases, and who pays for food & school fees	0 to 4

Table 5.1 (continued)

Food purchase diversity score	Among the food groups that made up the HDDS, the number of food groups that were consumed in the last week which were obtained by food purchase, as measured by the 7-day FFQ	0 to 9††
Crop diversity	Count of the number of crops grown on the farm in the last 12 months, using respondent recall and probing	0 to ∞
TAV production	Whether or not TAVs were planted	0/1
	Number of TAVs planted	0 to 5
	Acres planted in TAVs (paced)	0 to total farm size
	Amount harvested (kg) per 6-month season of long rains (April-Sept)	0 to [amount equivalent to 4x published yields (tons/acre)]
TAV marketing	Amount sold (kg) per 6-month season of long rains (April-Sept)	0 to [amount equivalent to 4x published yields (tons/acre)]
	Number of markets where farmer sold TAVs (in the categories of farmgate, local market, regional market, supermarket)	0 to 4
TAV income	Gross income from the sale of TAVs over the 6-month season (April-Sept)	0 to ∞
	Net income from the sale of TAVs over the 6-month season (gross-input costs)	0 to ∞
	Imputed income: value of TAVs grown over the 6-month season (mean farmgate price-opportunity cost)	0 to ∞
	Percent of gross income that women keep	0 to 100
	Women's gross TAV income per season (Gross income*percent women keep)	0 to ∞

*HDDS Food groups: cereals; roots/tubers; vegetables; fruits; meat/poultry; eggs; fish; pulses/nuts; milk/yogurt/cheese; oil/fat; sugar/honey; miscellaneous [253].
**IDDS Food groups: grains/roots/tubers; DGLV; other fruits and vegetables;

Table 5.1 (continued)

meat/poultry/fish; eggs; pulses/nuts; milk; oil/fat [253].
†Because dark green leafy vegetables (DGLV) are often mixed together, they were not counted individually; the maximum days any one TAV was consumed and the maximum days any one other DGLV was consumed were used in the count of micronutrient-rich foods (2 numbers, one for each group; not 8, one for each individual DGLV in the FFQ).
††The maximum food purchase diversity score was 9 instead of 12 because FFQ did not capture all possible foods, so grains/roots/tubers were combined into one group, fish (represented by dried anchovy) was combined with "other," and sugar/honey was excluded as a food group.

5.2.2 Statistical methods

Data were double-entered in CSPro data entry software [42], using electronic forms that looked identical to the printed survey questionnaire. Data were then imported into PASW statistical software, version 18.0 [247] for analysis. For descriptive statistics, equality of proportions was tested using Pearson's chi-square test statistic. Equality of means was tested using a one-way ANOVA. Longitudinal analyses were carried out as mixed effects models, examining the variables of interest as fixed effects, and controlling for district and village as random effects, where independent and dependent variables of interest were differenced (time 2-time 1). Thus, models controlled for time-constant household-level fixed effects. For categorical dependent variables, multinomial logistic regression modeled positive or negative change compared to no change (0). Cross-sectional analyses for child nutritional status were carried out on year 2 data only, because data on all explanatory variables were not available at baseline. Regression assumptions were checked using residual plots, normal probability plots, and histograms of dependent and independent variables. Where necessary, logarithmical or square-root transformations were used to improve functional form of models.

5.3 Results

5.3.1 Baseline household characteristics

The baseline characteristics of households surveyed are shown in Table 5.2. There are some significant differences between groups, reflecting the self-selection bias of households who chose to participate in the program. Households who participated to some extent in the program, whether they continued to participate actively or stopped participating after baseline, were on average wealthier and older than comparison households; related to those characteristics, they had more land and fewer children under age five, on average. While active participants had few children under five, a significantly greater percent of children in program households were underweight compared to comparison households. This was unexpected given the greater wealth of participant households, and indicates that undernutrition could be caused by care-related factors in this population, rather than food access. The sample size of children in active participant households was also very small (14), which amplifies the contribution of each malnourished child to the total percent; in fact five children were underweight in each of the comparison and participant groups.

There were significant differences at baseline between participant groups in TAV-related variables as well (Table 5.3). Consistently active participants were more likely to be growing and selling TAVs, and to be growing a greater number of TAVs, than baseline-only participants (those who stopped attending meetings after baseline); baseline-only participants in turn were more likely to grow and sell a greater number of TAVs than comparison households. Active participants also sold

Table 5.2: Baseline Demographics, Kiambu.

	Comparison (n = 77)	Baseline-only participants (n = 31)	Active participants (n = 61)
Years of school (head)	9.0	7.8	9.0
Years of school (mother)*	8.9	7.2	8.9
% female-headed households	13.0	19.4	9.8
Wealth (value of assets owned, geometric mean)	\$820 [a]	\$1427 [b]	\$1437 [b]
Land size (acres)	1.2 [a]	2.2 [b]	2.5 [b]
Age of household head (years)	43 [a]	56 [b]	50 [b]
Household size	5.0	4.4	5.1
Mean number of children under age 5	1.3 [a]	0.5 [b]	0.5 [b]
% U5 children <-2 WAZ	8.0 [a] (n=5)	0 [b]	35.7 [c] (n=5)

Notes: Equality of proportions was tested using Pearson chi-sq test statistic. Equality of means was tested using a one-way ANOVA. Means with different superscripts are significantly different using Tukey's HSD criterion. Means with no superscript are not significantly different.
The household "mother" (the person who cared for the reference child age 2-5 years or if no reference child, the person who prepared the majority of the household food) was sometimes the same as the head of the household, but usually not.

TAVs at a significantly greater number of market outlets than either baseline-only participants or comparison households, and planted approximately six times the acreage in TAVs that comparison households planted. Related to production activity, active participants harvested and sold significantly greater volumes of TAVs than comparison households, and earned a gross income from TAVS significantly higher than that of comparison households, as well as a higher imputed income (calcultated using the value of the TAVs grown rather than the price obtained). While there was no significant difference between groups in the percent of households where women were responsible for TAV production, in active participant households a significantly lower proportion reported that women decided whether to plant TAVs, indicating that households where men controlled TAV production decisions may have been more likely to join the program. There were no significant differences between groups in the percent of households where women sold TAVs nor the percent of TAV income or gross TAV income that women keep.

Table 5.3: Household TAV production and marketing at baseline

Among all respondents (n=169)			
	Comparison (n = 77)	Baseline-only participants (n = 31)	Active participants (n = 61)
% growing TAVs	40.3^{a}	71.0^{b}	96.7^{c}
Number of TAVs grown (out of 5)	0.69^{a}	1.87^{b}	2.56^{c}
% selling any TAVs	18.2^{a}	32.3^{b}	83.6^{c}
Number of markets where household sold TAVs	0.17^{a}	0.26^{a}	0.85^{b}
Among households who grew TAVs (n=112)			
	Comparison (n = 31)	Baseline-only participants (n = 22)	Active participants (n = 59)
Area planted in TAVs (acres)	0.007^{a} (28m^2)	0.016^{ab} (65m^2)	0.042^{b} (170m^2)
% households where women decide whether to plant TAVs	75.0^{a}	63.2^{ab}	43.1^{b}
% households where women are responsible for production	77.8^{a}	71.4^{a}	48.3^{a}
Among those who grew in season and had harvest data (n=71)			
	Comparison (n = 15)	Baseline-only participants (n = 9)	Active participants (n = 47)
Harvest (kg/6-mo season) (geometric mean)	55.8^{a}	60.8^{a}	395.8^{b}
Amount sold (kg per 6-month season)	22.0^{a}	39.7^{ab}	320.25^{b}
Gross TAV income per season (USD) (among only those who sold in parentheses)	\$9.52^{a} (\$29.36)	\$12.88^{ab} (\$46.22)	\$61.73^{b} (\$74.15)
Net TAV income per season (subtracting input costs)	\$5.54^{a} (\$13.31)	\$8.07^{a} (\$13.62)	\$33.22^{a} (\$38.82)

Table 5.3 (continued)

Imputed income (value of TAVs grown)	\$11.24^{a}	\$16.69^{ab}	\$85.97^{b}
% households where women sell TAVs	81.8^{a}	50.0^{a}	58.3^{a}
Percent of (gross) TAV income that women keep	81.4^{a}	66.7^{a}	67.3^{a}
Women's gross TAV income per season ("money in the pocket")	\$7.55^{a}	\$7.56^{a}	\$24.41^{a}

Notes: Equality of proportions was tested using Pearson chi-square test statistic. Equality of means was tested using a one-way ANOVA. Means with different superscripts are significantly different using Tukey's HSD criterion. Means with no superscript are not significantly different.

Comparison, baseline-only participants, and active participants had roughly equivalent diets at baseline (Table 5.4). The only significant differences between groups were that baseline-only participants consumed approximately 0.6 fewer food groups than comparison households, and active participants consumed approximately three more iron-rich foods per week than comparison households. These data show that diets in the study site are generally quite high-quality. While there is no universal cutoff score to indicate nutritional adequacy, a mean dietary diversity score of 7-8 food groups indicates a good diet by any proposed cutoff [251, 134, 99, 222]. There is also no cutoff for indicators of dietary variety or frequency of vitamin A-rich or iron-rich food consumption; it is assumed that more is better for nutrition, particularly in this population where low dietary variety and micronutrient deficiencies have been historical problems. These exact indicators have not been used before, and no cut-offs have been proposed. While there is no cut-off for adequate fruit and vegetable consumption, the mean consumption between 4-5 per day is within the range of recommendations to consume at least 400g of fruits and vegetables per day [294], although it still could be improved; as one national campaign states, for fruits and vegetables, "more matters" for health [29]. Fruit and vegetable consumption is likely to be an important factor in maintaining healthy diets in the future, as the nutrition transition progresses in East Africa.

Table 5.4: Diet at baseline, Kiambu, Kenya (n=169)

	Comparison (n = 77)	Baseline-Only Participants (n = 31)	Active participants (n = 61)
HDDS* (max=12) (Dietary diversity score= number of food groups)	8.14^{a}	7.52^{b}	7.82^{ab}
IDDS** (max=8) (individual child dietary diversity score)	5.77	5.80	5.93
HDVS*** (Dietary variety score= number of unique foods, standardized by enumerator)	14.13	13.48	14.16
IDVS***	-0.16	0.65	1.23
Fruit and vegetables consumed (number in the last 24 hours)	4.43	4.52	4.59
Frequency of vitamin A-rich foods consumed in 1 week (max=70)	14.17	14.52	16.23
Frequency of iron-rich foods consumed in 1 week (max=70)	16.83^{a}	17.39^{ab}	19.66^{b}

Notes: Equality of means was tested using a one-way ANOVA. Means with different superscripts are significantly different using Tukey's HSD criterion. Means with no superscript are not significantly different. *HDDS 12 Food groups: cereals; roots/tubers; vegetables; fruits; meat/poultry; eggs; fish; pulses/nuts; milk/yogurt/cheese; oil/fat; sugar/honey; miscellaneous **IDDS 8 Food groups: grains/roots/tubers; DGLV; other fruits and vegetables; meat/poultry/fish; eggs; pulses/nuts; milk; oil/fat ***Dietary variety scores were standardized by enumerator, since means between enumerators varied.

Figure 5.1 shows the percent of households surveyed who consume each food group out of the 12 food groups in the household dietary diversity score [253]. The figure reflects the generally highly diverse diets found in the sample. There were no significant differences between program groups for any food group. All households consumed grains and oil, and close to 100% of households consumed vegetables, milk, and tea (miscellaneous category). Households were relatively less likely to consume foods from the following food groups: fruit, and major protein sources: pulses, meat, eggs, and fish, which was almost never consumed in the study area. Protein deficiency is unusual in the study area, however, owing in part to high levels of milk consumption (both in frequency and quantity). Households reported that they did not usually consume pulses and meat or eggs on the same day, but rather, those foods were substitutes. The percentages of households consuming each protein-rich food category could reflect that norm, with total percentages of any protein-rich food adding up to approximately 80%. Fruit consumption was surprisingly low; even though fruits were often considered foods for children, these data reflect that in most households no one in the household, not even children, consumed fruits.[2] In general, children age 2-5 years in this site consumed the same diet as the rest of the household (as found by asking specifically if the reference child ate each food item listed for the household).

5.3.2 Association between program participation and dietary change

A main research question was whether program participation was related to change in household and child diets. Mean changes in dietary indicators were compared between active participants, baseline-only participants, and the comparison groups. The dietary indicators, each for both the household and the individual reference child, were:

[2] Starchy bananas were consumed often, and although they are botanically a fruit, they were coded as a root/tuber due to their role in the diet as an alternative starch to maize or rice.

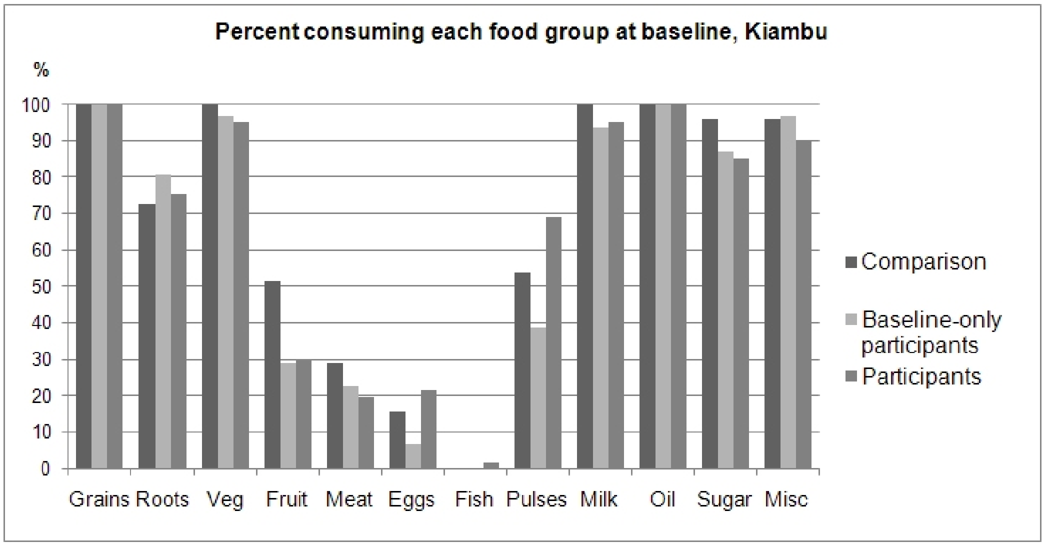


Figure 5.1: Baseline food group consumption, Kiambu

- Δ dietary diversity (food groups)
- Δ dietary variety (individual foods)
- Δ number of fruits and vegetables consumed
- Δ frequency of vitamin A-rich food consumption
- Δ frequency of iron-rich food consumption

All analyses adjusted for potentially relevant and confounding variables: women's reported purchasing decision-making power, change in household size, change in number of crops and animals produced on the farm, change in wealth, baseline wealth, number of children under age 5, and baseline value of the dependent variable. Analyses of the reference child's diet additionally adjusted for mother's education and the number of days the child was sick in the two weeks prior to the survey.

Program participation status was not a significant predictor of change in any of the dietary indicators except frequency of consumption of iron-rich foods in the household. Active participants had a significantly more positive change in frequency of consumption of iron-rich foods than comparison households (magnitude 2.57, p=0.025). (See Figure 5.2)

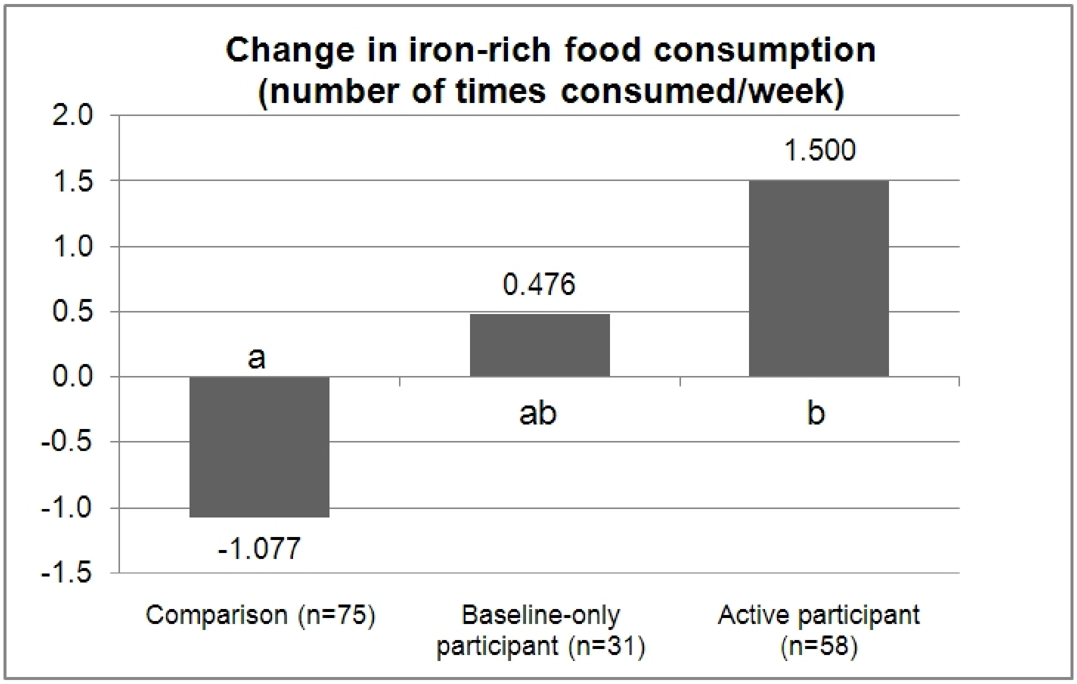


Figure 5.2: Change in iron-rich food consumption based on program participation
Notes: Means were adjusted for change in women's reported purchasing decision-making power, change in household size, change in number of crops and animals produced on the farm, change in wealth, baseline wealth, number of children under age 5, and baseline value of the variable. Models also controlled for district and village as random effects. **Means with different letters (a,b) are significantly different from each other at the p<0.05 level.**

In addition to the above dietary variables, program participation was not related to change in whether or not any vegetables in general, or dark green leafy vegetables (DGLV) were consumed by households or children (which is how it would influence HDDS through home consumption). DGLV were already very commonly consumed at baseline (consumed by 70% of all households in the 24 hours prior to the survey). Of note, only one child in the whole sample stopped eating DGLVs compared to baseline (in a non-participant household); DGLV are very common for children to consume in this population. To allay worries that program participation could cause an increase in incomes that would result in more junk food consumption, the relationship between program participation and change in consumption of processed foods was tested; no association was found. In the population as a whole, however, junk food consumption seemed to be increasing slightly, from 25% at baseline to 34% at follow-up.

Another hypothesis was initially that program participation may have had a stronger effect on those with the poorest diets; that is, it may have modified the relationship between baseline diet and change in diet (which is typically a negative association due to regression to the mean). Upon examination of the data, however, the meaningfulness of this hypothesis test was limited by the small number of households who had a poor diet. In other studies using dietary diversity scores, a cut-off of 4 food groups has been used, at or below which a diet may be considered "poor." This is a somewhat arbitrary cut-off, and the number of food groups associated with "poor" diets varies by circumstance and site [222]. There is no accepted cut-off for "poor" vs. "good" dietary diversity scores. However, whatever cut-off could be used, there are very few households in this study with certifiably poor diets, at least in the sense of being associated with undernutrition. Only six households consumed less than six food groups, and 12% consumed less than seven; as noted above, 7 food groups indicates a relatively good diet by any proposed cutoff. The mean, median, and mode HDDS in this sample was eight food groups, which indicates a population with an overall good diet. Given the very few households with low dietary diversity scores, the power this study had to detect an effect specific to households with poor diets was limited.

Table 5.5: Baseline household dietary diversity score (HDDS) (max=12)

	HDDS	Frequency	Percent	Cumulative Percent
Valid	4	3	1.8	1.8
	5	3	1.8	3.6
	6	14	8.3	11.9
	7	35	20.7	32.7
	8	61	36.1	69.0
	9	36	21.3	90.5
	10	15	8.9	99.4
	11	1	.6	100.0
	Total	168	99.4	
Missing		1	.6	
Total		169	100.0	

5.3.3 Program participation is related to perceived change in economic well-being

In response to the question "Do you think that your family is in better, the same, or worse economic conditions now compared to last year?" in the *follow-up* survey, almost two thirds of all surveyed households in Kiambu reported a decline, while 25% reported an improvement. The main reasons for an improvement or decline, as summarized from open-ended responses, are listed below.

The global 2008 price shock affected Kenya particularly severely [74], which is reflected in these data. Most households reported being in worse economic shape than in 2007, and the vast majority of worse-off households (82%) cited high prices as the reason, either in general or specific to food and inputs. That is, 53% of the whole sample reported being negatively affected by high prices. These data refute an initial common assumption that the 2008 food price spike would benefit farmers. Some farmers did benefit from high prices - of the 25% who said their economic situation improved, 28% cited high prices or "good sales" of

Table 5.6: Top 5 reasons why economic situation got better or worse (% among people categorizing themselves as "better" or "worse" off than last year)

Better: 25% of the total sample	**Worse:** 62% of the total sample
Good harvests (24%)	High prices in general; cost of living increase (48%)
New income source (24%)	High input prices (18%)
Good sales (15%)	High food prices (16%)
Good prices (13%)	Poor harvests (16%)
Increased livestock holding or productivity (13%)	Poor sales (8%)

their produce as the reason. That is, 7% of the whole Kiambu sample benefited from high prices, possibly due to the price spike, possibly due to other factors - much less than the 53% who were negatively affected by high prices. In focus group discussions, farmers complained bitterly about extraordinary price increases of fertilizer (both chemical and organic) and transport, which made it harder to make money by selling their produce in lucrative city markets. Kenya was also struck with crippling post-election tribal clashes in January 2008, which effectively stopped all transport and domestic commerce. While Kiambu was not a hotspot for violence and no farmers in the survey were injured, they did report their vegetable crops rotting in the field for want of markets that month. At least one household cited the post-election violence as the main reason why their economic situation had deteriorated between 2007-2008.

A multinomial logistic regression was used to assess what variables were associated with a decline or improvement in economic well-being, relative to no change. The independent variables included program participation, district, change in household size, baseline wealth, and household head age.

The overall model had a significance of 0.020, and a McFadden pseudo-R-square of 0.11. Active participant households (n=58) were 8.6 times more likely than non-participants (n=75) to report that their economic situation had improved (p=0.026). Active participants also appeared to be more likely than baseline-only participants (n=31) to report an improved economic situation, but the association did not reach significance (p=0.065). Program participation was the only significant variable in the model explaining improved economic situation.

5.3.4 Assessment of program impact pathways: Did production and marketing affect changes in diet-related variables?

It appears that program participation had a limited effect on diet, but a significant relationship with perceived economic well-being. Those relationships do not complete the analysis of how the program may affect diet, however. Part of the program evaluation involves understanding whether the main intermediate program goals could be expected to influence diet. In the case of the TF Project, the program theory was that growing more TAVs could influence diet either directly, through increased TAV consumption (which might affect overall dietary diversity, and consumption of vegetables, vitamin A-rich, and iron-rich foods); or indirectly, through increased income that could be used to purchase better diets, particularly if that income were in the hands of women.

Figure 5.3 illustrates the pathways through which the program aimed to affect diet. TAV production and marketing were two primary outcomes the program sought to increase through its activities, because according to the program planners' concept or theory, these outcomes would cause other household effects which would in turn affect diet. This section presents results on tests of program theory: that TAV production and marketing was associated with dietary outcomes.

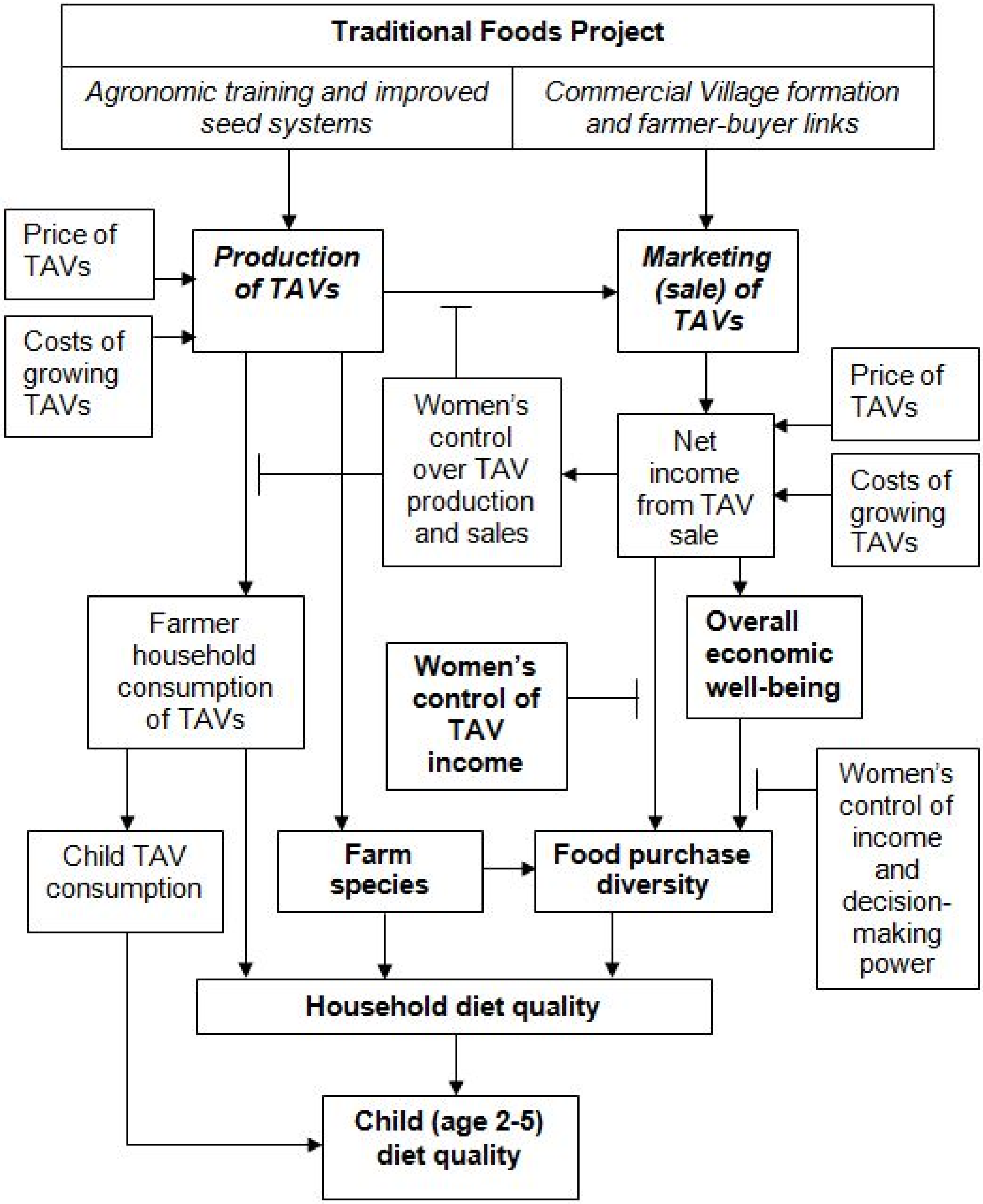


Figure 5.3: Program Impact Pathways: Steps between TF Project activities and dietary outcomes. Note: Items in bold are the intermediate outcomes assessed in the evaluation of program impact pathways. Items in italics (production and marketing) are the primary predictors tested.

Program effect on TAV production and marketing

Whether the program actually increased TAV production and marketing is the first link of the chain of relationships from program participation to diet. There was a significant relationship between program participation and three production and marketing indicators. Active participants significantly increased the number of TAVs they planted by 0.839 TAVs, compared to a decrease of 0.391 TAVs among non-participants ($p<0.001$) and a decrease of 0.302 TAVs among baseline-only participants ($p=0.001$). The number of markets active participants were able to access significantly increased by 0.364 compared to a *decrease* of 0.218 markets accessed by non-participants ($p=0.007$). There was a significant interaction between program participation group and area of TAVs cultivated. Active participants who grew larger areas of TAVs at baseline had a larger positive change in area planted in TAVs than the non-participant or baseline-only participant groups. (See figure 5.4)

Although analyses showed positive trends in all cases toward active participants harvesting and selling more TAVs and earning more net and gross income than non-participants, differences between groups were not statistically significant at the $p<0.05$ level, mostly due to small sample sizes and large errors in harvest amount estimation. No significant differences were observed between groups for women's control of TAV income. Detailed results for changes in TAV production and marketing based on program participation group can be found in Appendix B. As seen in Appendix B, active participants were the only group for which change in mean gross and net income from TAVs exceeded the change in mean implicit value of the crops; participants were able to capture value from TAV sales in a way that the other groups were not.

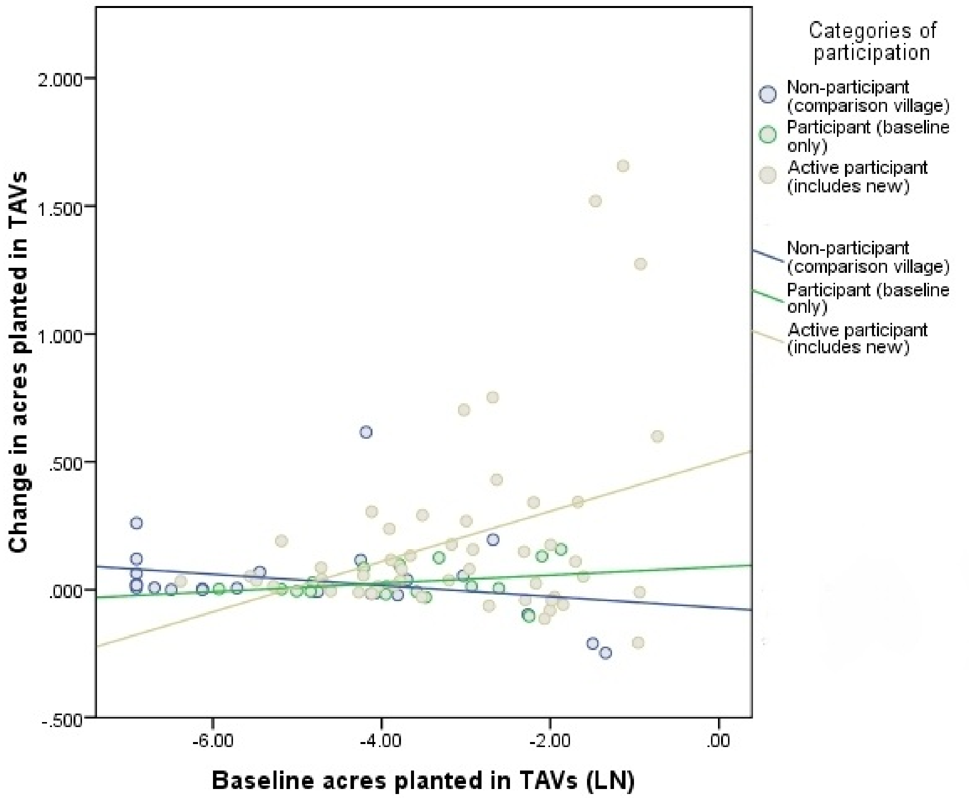


Figure 5.4: Change in acres planted in TAVs by program group

Are production and marketing related to improved diets or diet-related factors?

This section shows the result for the hypothesis tests of whether (a) TAV production (modified by program participation) and (b) marketing were related to improved diets or hypothesized diet-related factors (economic well-being, women's control of income, food purchases and farm diversity) in any way.

Using a mixed model to control for the survey design of households clustered in districts and villages, change in diet and diet-related factors was predicted by (a) change in TAV production and covariates, and (b) change in TAV sales and covariates. The interaction term between program participation and TAV production was of particular interest because the hypothesis is that those who grow TAVs and are *in the program* will have better income-generating opportunities, which can turn into diversified food purchases and better diets. Results are shown in Tables 5.7 and 5.8, respectively.

The one dietary variable for which there was a significant relationship with change and TAV-growing was change in fruit and vegetable consumption (Table 5.7). Each additional TAV grown was associated in a 0.49 unit increase in the number of fruits and vegetables eaten the day before the survey ($p=0.021$). TAV production was the only significant variable in the model other than baseline fruit and vegetable consumption, which was strongly negatively correlated with change in fruit and vegetable consumption as expected. The interaction term was not significant in any of the models.

For diet-related variables (Table 5.8), the only significant model was the one predicting farm diversity. Each additional TAV grown was associated with a 1.1-species increase in crops or animals produced on the farm ($p<0.001$). That result means that households are adding TAVs to the crops they already grow, rather than substituting whole crops: each TAV planted is increasing the diversity of on-farm food production by approximately one. The only other significant variable in that model predicting change in crop diversity was baseline wealth (ln), which showed that a doubling of wealth was associated with a 0.59-crop increase. (See B for the full results table.)

Table 5.7: Change in diet based on program participation and program-intended outputs

	Direct predictor	*Program theory-based predictors*	
	Program participation*	Δ TAV production**	Δ TAV marketing***
Outcome variables	n=169	n=169	n=67
Δ dietary diversity (food groups)	NS	NS	NS
Δ dietary variety (individual foods)	NS	NS	NS
Δ number of fruits and vegetables consumed	NS	Each additional TAV grown was associated in a 0.49 unit increase in the number of fruits and vegetables consumed per day (p=0.021)	NS
Δ frequency of vitamin A-rich food consumption	NS	NS	NS
Δ frequency of iron-rich food consumption	Active participants had a significantly greater positive change in consumption of iron-rich foods than comparison households (2.57 more iron-rich foods per week, p=0.025)	NS	NS

*Analyses controlled for baseline wealth, change in wealth, number of children under age 5, change in household size, change in number of crops produced, change in women's reported purchasing decision-making power, and baseline value of the outcome variable. Models also controlled for district and village as random effects. **Analyses controlled for baseline wealth, change in wealth, number of children under 5, change in household size, change in number of crops produced, program participation, the interaction between program participation and TAV production, and baseline value of the outcome variable. Models also controlled for district and village as random effects. ***Analyses controlled for baseline wealth, change in wealth, and program participation. Models also controlled for district and village as random effects.

Table 5.8: Change in hypothesized diet-related variables based on program participation and program-intended outputs

	Direct predictor	*Program theory-based predictors*	
	Program participation*	Δ TAV production**	Δ TAV marketing***
Outcome variables	n=169	n=169	n=67
Δ Economic well-being from 2007 to 2008†	Active participant households were 8.6 times more likely than comparison households to report an improved economic situation (p=0.026).	NS	NS
Δ Women's income kept from TAV sale	NS	NS	NS
Δ Food purchase diversity score (whether each of 9 food groups was purchased, based on the FFQ)	NS	NS	NS
Δ Farm diversity (total number of crops and animal species produced on the farm)	NS	Each additional TAV grown was associated with a 1.1-species increase in crops or animals produced on the farm (p<0.001).	NS

*Analyses (except for predicting change in economic well-being) controlled for baseline wealth, change in wealth, number of children under age 5, change in household size, and baseline value of the outcome variable. Models also controlled for district and village as random effects. **Analyses (except for predicting change in economic well-being) controlled for baseline wealth, change in wealth, number of children under age 5, change in household size, program participation, and baseline value of the outcome variable. Models also controlled for district and village as random effects. ***Analyses (except for predicting change in economic well-being) controlled for baseline wealth, change in wealth, program participation, and baseline level of the outcome variable. Models also controlled for district and village as random effects. † The multinomial logistic models to predict change in economic well-being controlled for baseline wealth, age of household head, change in household size, and district.

5.3.5 Connecting the dots: how hypothesized diet-related variables relate to diet

Economic shift and food purchase diversity

Active program participation was associated with increased odds of a positive shift in overall economic well-being. Economic well-being is hypothesized to contribute to improved diets through increased food purchase diversity, as shown in the conceptual framework 5.3.

To test that hypothesis, change in food purchase diversity score was modeled as a function of reported economic shift (positive, neutral, negative), and other factors that could affect changes in food purchases: baseline wealth (ln), change in farm diversity, change in women's purchase decision-making power, program group, and baseline food purchase diversity score. District and village were controlled for as random effects.

The result was that reported overall economic shift was highly significantly related to change in food purchase diversity; those who reported an overall improvement in their economic situation increased their food purchase diversity by 0.7 food groups compared to both those who reported an economic decline (p=0.002) and by the same amount compared to those who reported no change (p=0.037). Reported economic shift was the only variable that predicted change in food purchase diversity.

The paper had set out to test if women's income control or decision-making power were associated as independent predictors of food purchase diversity or as effect modifiers, but neither variable proved useful in prediction models. Because so few households sold TAVs in both years (n=57, 44 of which were in the program group), the analysis lacked statistical power to test the association. The measure of women's economic decision-making power appeared to poorly measure the intended construct, since the score was not very variable between households, while qualitative inquiry and observations suggested that variation did exist between households. Validated indicators of women's decision-making power within households would be useful for future studies.

Food purchases, farm diversity, and dietary diversity

It was hypothesized, according to the program theory, that food purchase diversity and farm diversity would independently be positively associated with dietary diversity, because home production and food purchases are farmers' main sources of food.

To test these hypotheses, both cross-sectional and longitudinal models were tested, using all observations from baseline and follow-up.

For the cross-sectional analysis, mixed models were used to predict dietary diversity (HDDS) and dietary variety (HDVS) as a function of farm diversity, food purchase diversity, wealth, women's decision-making power, household size, numb er of children less than five years old, mother's education level, household head's education level, land access, program group, and year as fixed effects. Models controlled for district, village, and household as random effects (to control for the non-independence of observations).

The longitudinal analysis also used mixed models to predict change in dietary diversity as a function of change in farm diversity, change in food purchase diversity, baseline wealth, change in wealth, change in women's decision-making power, change in household size, number of children under five years old, and household head education. District and village were controlled for as random effects.

Cross-sectionally, both food purchase diversity score and farm diversity, as well as mother and household head education, were highly significantly associated with dietary diversity and variety scores after controlling for wealth, education, and other confounders ($p<0.001$) (Table 5.9). Also, food purchase diversity and farm diversity were highly negatively correlated ($R=0.23$, $p<0.001$): the more variety of food produced on-farm, the less farmers needed to purchase a variety of food. Only food purchase diversity was significantly associated with child dietary variety score, although farm diversity approached statistical significance ($p=0.068$).

Longitudinally, only change in food purchase diversity was a significant predictor of HDDS; each additional food group purchased was associated with 0.15 additional food groups consumed ($p=0.039$). Change in farm diversity was not significantly associated with change in household dietary diversity score. Models predicting change in household and child dietary variety were not significant.

5.3.6 Relationship between dietary diversity and child nutritional status (weight for age)

A main reason for measuring dietary diversity and dietary variety as outcomes is their direct association with nutritional status. In this sample, the relationship between dietary diversity and nutritional status was tested using a multiple linear regression on the available data. Results are shown in Table 5.10.

Individual child dietary variety (IDVS) was significantly positively associated with child weight-for-age z-score (WAZ). Individual child dietary diversity score (IDDS), tested in a separate regression, was not significantly associated with child WAZ. Younger age, greater months of exclusive breastfeeding, fewer months sick in the last year, greater mother age, greater wealth, and smaller household size were all significantly associated with greater WAZ. A greater number of days that someone else other than the main caretaker took care of the child, and greater number of months since last deworming were also associated with greater WAZ, which was

Table 5.9: Predictors of dietary diversity and dietary variety

	Model 1		Model 2		Model 3	
	Dietary diversity (HDDS)		Household dietary variety (HDVS)		Child dietary variety (IDVS)	
	n=328		n=328		n=171	
	Est. [S.E.]	p-value	Est. [S.E.]	p-value	Est. [S.E.]	p-value
Farm diversity (# crop and livestock species)	0.054 [0.016]	0.001	0.211 [0.040]	<0.001	0.095 [0.052]	0.068
Food purchase diversity score	0.143 [0.050]	0.004	0.618 [0.126]	<0.001	0.565 [0.153]	<0.001
Wealth (log value of assets owned)	0.116 [0.069]	0.096	0.252 [0.179]	0.161	-0.161 [0.153]	0.404
Women's decision-making power score	0.026 [0.092]	0.779	-0.072 [0.234]	0.761	-0.218 [0.286]	0.448
Household size	-0.045 [0.044]	0.312	-0.069 [0.116]	0.554	0.126 [0.166]	0.448
Number of children <5 years	0.171 [0.111]	0.124	0.737 [0.292]	0.012	0.108 [0.420]	0.798
Caretaker's education (years)	0.056 [0.026]	0.036	0.121 [0.070]	0.087	0.181 [0.092]	0.051
Household head's education (years)	-0.006 [0.023]	0.810	0.122 [0.062]	0.052	0.158 [0.071]	0.028
Land access (acres)	0.003 [0.040]	0.942	-0.109 [0.103]	0.289	0.181 [0.159]	0.256
Program group	-0.409 [0.239]	0.137	0.081 [0.683]	0.909	0.976 [0.546]	0.077
Year	-0.123 [0.108]	0.256	0.036 [0.260]	0.891	-0.224 [0.321]	0.486

Note: Models control for household ID, village, and district as random effects.

unexpected. The alternate caretaker may represent school attendance, which could be associated with greater WAZ for a variety of reasons. The model was also run

Table 5.10: Factors associated with weight-for-age z-score (Kiambu, Kenya)

	Dependent variable: WAZ (children age 2-5 years) (n=74)	
	Est. [S.E.]	p-value
Sex=female	-0.129 [0.187]	0.492
Child's age (months)	-0.030 [0.008]	0.001
Months of exclusive breastfeeding	0.144 [0.067]	0.036
Child's dietary variety (IDVS) (# unique foods)	0.083 [0.033]	0.015
Months child was sick in last year	-0.839 [0.241]	0.001
Days/week someone besides mother takes care of child	0.077 [0.037]	0.044
Child is fed special foods apart from the rest of the family	-0.054 [0.195]	0.785
Mother's education (years)	-0.057 [0.043]	0.196
Mother's age (years)	0.031 [0.014]	0.025
Wealth (value of assets owned)	0.120 [0.088]	0.177
Housing quality index (factor analysis score)	0.689 [0.159]	0.667
Household size	-0.189 [0.006]	0.006
Months since child was dewormed	0.040 [0.018]	0.027

with household-level diet variables (HDDS and HDVS). Neither household-level predictor was significant, showing that individual-level data is more highly predictive than household-level, and it is worth the extra costs of collection in order to gain precision.

5.4 Discussion

Two associations were observed between program participation and dietary changes. Program participation was directly associated with increased consumption of iron-rich foods. The connection with iron-rich food consumption seems important given the number of people who talked about having problems with anemia. Also increased TAV production - a direct impact of the program - was associated with increased fruit and vegetable consumption, which is important given the evidence of a dietary and nutrition transition in Central Kenya, where fruit and vegetable consumption tends to decrease to the detriment of public health and nutrition. Neither program participation nor TAV production and marketing were observed to be associated with overall improved dietary diversity.

Program participants were more likely to have an improved economic situation, however, which was positively associated with increased food purchase diversity score, and food purchase diversity score was strongly significantly associated with higher dietary diversity both cross-sectionally and longitudinally. Also, program participation was associated with growing more TAVs, which was highly significantly related to increased on-farm crop diversity, which was significantly related to dietary diversity and variety cross-sectionally. Finally, dietary diversity and variety are typically related to child nutritional status, and the relationship was observed in this sample as well for dietary variety (IDVS). IDDS was likely not variable enough in this sample to observe differences in nutritional status, as approximately 85% of children consumed 5-6 food groups.

Overall, there seems to be some evidence that the program outputs have to do with increased food purchase diversity and increased on farm diversity, which are direct inputs to dietary diversity.

This chain of logic validates part of how the program was supposed to improve diets and ultimately nutrition, even though a direct effect of program or program outputs on dietary diversity was not observed. Figure 5.5 summarizes the relationships observed and not observed.

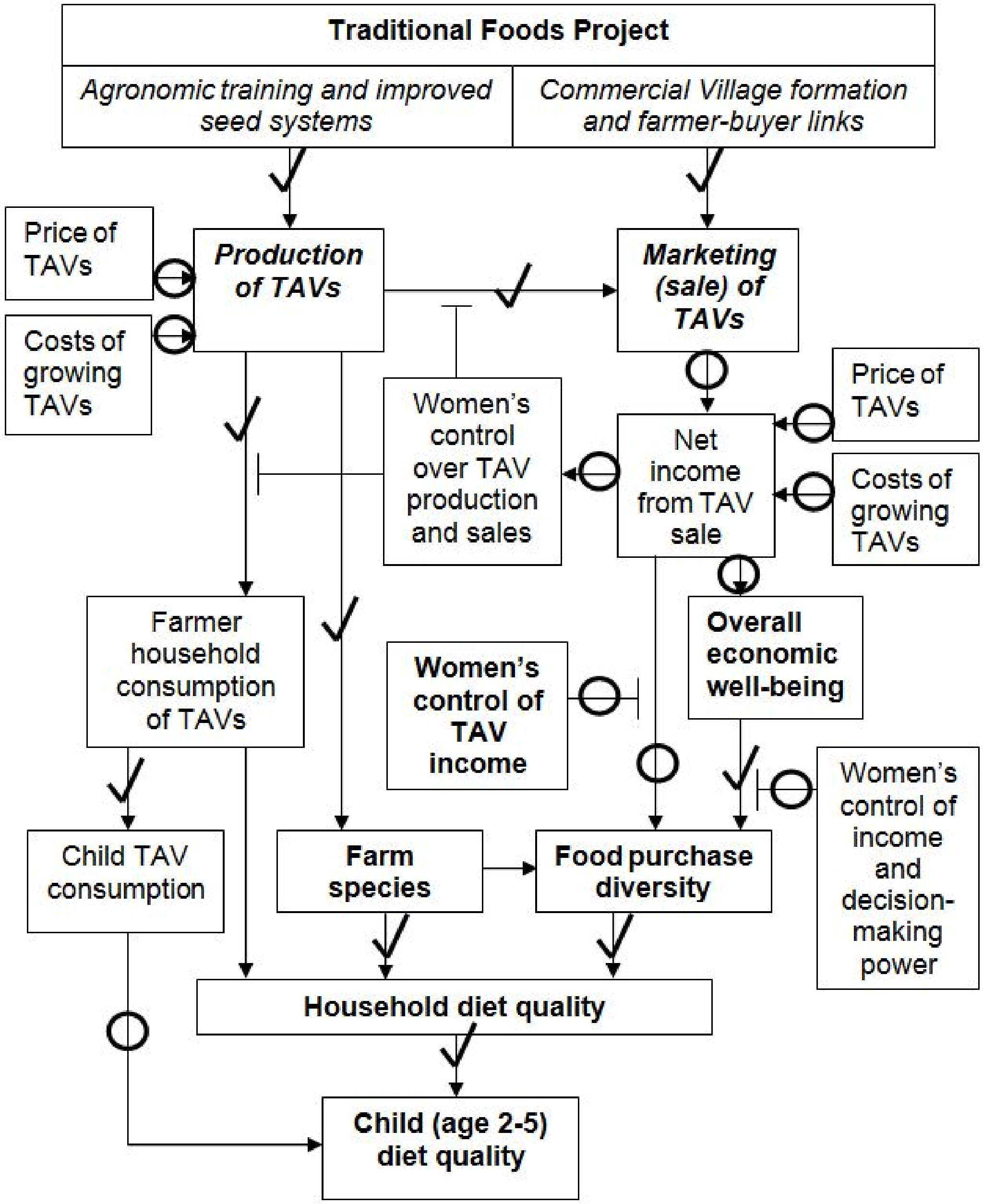


Figure 5.5: Results summary: How TF Project activities were related to dietary outcomes

Note: Check marks correspond to relationships where significant associations were observed. Circles correspond to relationships that could not be tested.

5.4.1 Plausibility and power

Based on baseline characteristics of households, it became clear that not all outcome indicators would have been expected to show changes based on program participation. There was little intra-household variation in HDDS and little intra-individual variation in IDDS over the one-year period between surveys. The majority of households and individuals shifted 0 or 1 food groups between years. Although the study was powered to detect a difference between program groups based on as little as a 0.5-unit change in dietary diversity score, in reality the unreliability of the HDDS and IDDS is most likely greater than 0.5-1 units. There are three main sources of measurement error of dietary diversity scores: (1) true day to day variation (diet on a single day may not perfectly represent usual diet), (2) inaccurate recall by the respondent, and (3) variation in skill or thoroughness of interviewers in eliciting dietary information. Review papers have detailed the issues with error in 24-hour recalls, some of which are applicable to dietary diversity score measurement [13, 55]. For this population, diet is not very variable from day to day (except switching of main protein sources, as noted above), so that a single-day recall is a reasonable approximation of usual dietary diversity. It was not possible to estimate inaccurate recall, but interviewers were trained to probe in order to minimize inaccuracies in respondents' recall. Inter-rater reliability was approximated by comparing the frequencies of dietary diversity scores obtained for each interviewer, which were expected to be roughly the same since each interviewer interviewed a presumably random sample of all survey respondents. The curves overlapped well in both survey years.[3] Despite the effort to reduce all three sources of error, the nature of dietary measurement based on a 24-hour recall is imprecise for individuals and households, and the small changes observed within many households may have been due to error rather than true changes based on the program or other factors.

Another important consideration in the use of dietary diversity scores is po-

[3]In surveys solely interested in measuring dietary diversity of food groups consumed, rather than individual foods, a series of yes/no questions about food groups, such as that proposed by FANTA [253] could potentially reduce interviewer bias.

tential to benefit. In this sample, almost 90% of households surveyed consumed 7 or more food groups, and at that level of dietary quality, large changes were unlikely. Households with high dietary diversity do not have room to increase their dietary diversity and are unlikely to rapidly reduce their dietary quality even in the face of income shock; rather, they might reduce assets or housing quality first, to protect food consumption. Households with *low* dietary diversity, however, are likely to increase their dietary diversity rapidly if they gain access to resources. Based on this research, it is not recommended to use HDDS or IDDS as outcome indicators in situations where dietary diversity is generally high. In contexts where dietary diversity is very low, however, HDDS and IDDS could be useful outcome indicators. Dietary variety or number of fruits and vegetables consumed may be better indicators of good diets than dietary diversity scores in populations which appear to be undergoing a nutrition transition, and to be at risk for shifts toward obesogenic diets.

Although this intervention was ideally structured to increase DGLV consumption, change in DGLV consumption as a food group was also not possible, since nearly all households consumed DGLV at baseline.

Changes in variety of fruit and vegetable consumption, iron-rich food consumption, and vitamin A-rich food consumption were possible, particularly because these indicators were not bounded by an upper limit. Program-associated changes in two of these indicators were observed. Change in fruit and vegetable consumption was plausible based on increased TAV production and associated crop diversity, which could provide a greater diversity of accessible vegetables to the household. Change in iron-rich food consumption is plausible based on improved economic situation among participants and related increased food purchase diversity scores. A dose-response effect was seen in change in iron-rich food consumption based on program group, which increases confidence in plausibility.

The study lacked power to detect differences in income from TAVs. Sample size for production and marketing variables was unexpectedly small, mostly because among many of the people who grew TAVs, they reported that the TAVs were not in season. Additionally, harvest (and by extension, sales and income) was extremely difficult to estimate for these crops and there is probably substantial error - only the most implausible estimates were eliminated, but even if an estimate was plausible, it was not necessarily correct. Small sample size combined with large standard errors or estimates reduced the chance of seeing significant differences. Results in Appendix B show that there was a strong trend that the changes among participants were much larger and more positive than changes among non-participants; the small sample size and large standard errors probably account for why the differences between program groups were not significant.

There was an even smaller sub-sample size for analyzing the program's impact on women's income control. Sales variables could accommodate non-marketers who started selling in the second year (the difference was follow-up sale amount minus zero), but the percent of income women controlled only included households which sold in both years - because if the household was not selling any TAVs, the question about how much income the woman controlled was not applicable. The number of households selling in both years was only approximately 60, and some of those households had implausible harvest (and by extension, sale) estimates. Therefore the study could not answer the question of how women's income control affected food purchases and overall diet.

Although this survey could not adequately quantify the true income effect of TAV production, results shown in Appendix B show trends toward increased income for participants, and no significant changes in whether the income was controlled by women. On average, women kept 70-80% of TAV income, so that among some households that were able to produce TAVs and take some to market, the extra cash (or the in-kind contribution to income, saving women from having to purchase or collect vegetables outside their farm) could have helped stabilize household economic well-being.

5.4.2 Conclusions

In sum, based on the changes that were possible to observe, there is evidence that the program and its key outputs of TAV production and marketing affected certain parameters of diet quality and other factors leading to optimal child and household nutrition. Fruit and vegetable consumption appears to have increased based on increased TAV production, and iron-rich food consumption appears to have increased based on program participation, possibly through increased economic well-being, which was related to food purchase diversity, in turn related to dietary diversity. Increased TAV production was also related to increased farm diversity.

An important finding was that both food purchases and on-farm diversity are strongly significantly associated with diverse diets, and on-farm diversity appears to substitute for food purchase diversity. This result is intuitive, but agricultural policies often do not sufficiently recognize the importance of on-farm diversity to diets. Food purchase diversity is clearly important, and is affected by household income and economic well-being, which many programs aim to improve. Food purchase, though, is not the only important determinant of dietary diversity for farmers, even among net buyers. The results of this analysis are limited because they are all based on household decision-making rather than exogenous variables, but these data reflect the reality observed in the field: from interacting with farmers in the study site and hearing them talk about their household food decisions, food crop availability on the farm plays a substantial role in dietary diversity in these sites. Further studies are needed with more precise measurements of diversity and seasonal availability to replicate and expand these results linking agricultural and dietary diversity.

Although there was no direct effect of program participation on dietary or nutritional outcomes, the analyses described here show evidence for pathways from agriculture to nutrition through both the income and home consumption pathways. The linkages are indirect, and were observable only through an analysis of program impact pathways. In evaluations of agricultural programs, analyses that link agriculture to nutrition through program theory analysis are needed. Using such analytical techniques can generate further evidence to test links between intermediate indicators, such as crop diversity and food purchase diversity, and nutritional status. Intermediate indicators may be more tangible targets for agricultural programs to aim for than child nutritional status indicators, and if upheld by enough evidence, can be instrumental in integrating more nutritional goals and activities into agricultural programs.

CHAPTER 6

CROP DIVERSITY AND DIETARY DIVERSITY

6.1 Introduction

This paper aims to address three of the questions associated with whether increased farm diversity is good for nutrition. First, it is unclear whether farm diversity is associated with dietary diversity. If it is, there are questions as to whether that association likely arises from home consumption, or from income that was used to purchase a diversity of foods. Finally, whether crop diversity is related to women's status and income control is unknown. The research also briefly examines farmers' motivations to grow a diversity of foods, which may have to do with available markets as well as household food security.

6.1.1 The question of diversity for small farmers in sub-Saharan Africa

In sub-Saharan Africa, many major donor organizations have identified a primary need as increasing staple crop production, by the logic that in many parts of Africa, there are seasonal and chronic food shortages, grain production is well below yields in other regions, and the need for calories will only increase as the population grows. There is also concern that an extreme focus on staple crop production would ultimately undermine food security and nutrition, by the unintended consequences of reduced crop and varietal diversity and related environmental effects, and reduced opportunities for participation by women.

Programatically, crop diversity is often ignored as a strategy for nutrition, for reasons not the least of which is lack of an evidence base. Important research questions are, Does crop diversity help small farmers? If so, how and in what circumstances? Are there diminishing returns to adding more crops, and is there a point at which additional diversity does not matter? The answers to these questions would have large ramifications on agricultural programs and policies targeted at smallholder farmers.

It is striking that almost no research has tried empirically to answer the question of whether crop diversity matters for the nutritional well-being of small farmer households. Recent research has made inroads into the question of whether dietary diversity is good for nutrition [222, 251, 134, 99, 255, 17, 8]. If diversity in small farms is causally related to dietary diversity, then there is a somewhat strengthened basis for the argument that crop diversity may be good for nutrition.

This large, needed research agenda harkens to the past. Thirty to forty years ago, the big question in agriculture-nutrition research was whether cash cropping helped or harmed nutrition - the basis of thought being that it may increase income, but decrease home-produced diets. Which had a bigger impact on nutrition? Whether agricultural diversification helps or harms nutrition is essentially a different framing of the same basic question. "Cash vs. food crops" has become "monoculture vs. diversity." Growing more kinds of crops presumably improves food self-sufficiency for small farmers, but does it decrease income-generating potential, presumably from the opportunity cost of forgoing economies of scale on a specific crop to be sold? Which has a bigger impact on nutrition?

The re-framing reflects important realizations about the realities of the small farmer with two acres of land and few other income sources. Firstly, it better reflects the reality that all food crops farmers grow are usually both cash crops and home-consumed - and that the cash value of even "minor" food crops can be substantial, depending on the agroecosystem and market situation where the farmer is located. It is still often assumed that fruits and vegetables are "home garden" crops, and discussing them connotes the goal of self-sufficiency. New market realities, however, are that fruits and vegetables and other "minor" crops can have the highest potential for value addition and sale. Diversifying crop production to include vegetables can no longer be thought of as decreased cash-crop production and increased subsistence, rather it is potentially both increased self-sufficiency and increased cash-cropping at the same time.

The income-generating potential of minor crops invites the second realization encapsulated in the "monocrops vs. diversity" framing: that men and women do not control each type of crop, and the income gained from it, equally. Earlier research on the "cash vs. food crops" debate brought an awareness of gender and intra-household decision-making to the fore [167]. One of the main findings of the cash crop studies was that the higher incomes from cash crops did not always have as large of an effect on child nutrition as was hoped or expected, and one reason was that women rarely had control over this cash crop income. Women, being the main caretakers and food providers and preparers in the family, were most in touch with the daily needs of the household and children for food and health care, and when they had money they controlled to use on those things, child nutrition was better. So, the theory goes, if women can control some of their own crops and income, they have a better chance at feeding the family; but naturally that comes at the expense of some land and other resources for the main commodity crops. Is having a possibly larger household income in the hands of men only, or a possibly smaller total household income but controlled by both men and women, better for nutrition? The question of whether diversification requires more or less of women's labor and time is also highly relevant to the question of whether it would improve household nutrition: if there is indeed a tradeoff between income control and time (which is an uncertain assumption), are women's caretaking practices better with more time or more money?

A third realization captured in the re-framing is the importance of seasonality to intermittent food insecurity in small farmer households. In "monoculture" it is assumed that harvest happens once or at most a few times/year, and so large payments come to the household sporadically. (Although this may not be true for all cash crops.) In "diversity" the idea is that one crop or another is always in season, and some small amount of new cash income can be put in the farmer's pocket at any time of year. Are large lump-sum payments or small, sporadic payments (which may total less overall) better for nutrition? Evaluations of cash crops suggest that lumpy income is problematic for nutrition [198] - particularly where there are few options to save it, and also possibly due to the psychology of having a lot of money at once, with a feeling of less obligation to save it for the future. Income security is also important: if everything is invested in one crop and that one crop fails, all income will be foregone. Farmers may choose to plant diverse crops as a risk-mitigation strategy [248]. Risk mitigation through diversity is gaining increased attention recently due to discussion about farmer adaptation to climate change [273, 100].

The shift in framing also reflects a shift in thinking in the nutrition community. During the "cash vs. food crops" era, nutrition was mainly thought to be an issue of adequate calories and protein - which could mostly be gotten from a bumper crop of maize. (Particularly if it had high lysine.) Micronutrients then became important in international nutrition agendas, and with them, came greater focus on the need for dietary diversity. Dietary diversity is a concept that is gaining traction as an indicator of adequate diet, a marker for probable good nutritional status, and the heart of food security [253, 8, 103]. This is also important as many parts of the world experience a nutrition transition related to simplification of diets to refined grains, fats, and sugars; greater dietary diversity and botanical dietary variety are indicators of good diets on both the undernutrition and overnutrition side. As such, "monoculture vs. diversity" takes on greater relevance to nutrition as it is thought of today; yet up to now, few studies have assessed the relationship between crop diversity and diet or nutritional status. One study has shown that number of crop species cultivated was significantly associated with adult nutrient adequacy in Mali [258]. One very recent study has looked at how species richness relates to functional diversity, food diversity and nutritional outcomes, and showed a strong correlation in Western Kenya between crop species variety richness and functional diversity for providing iron, and an inverse relationship between species richness and anemia [47].

Finally, re-framing the question of "cash vs. food crops" as a question of "monoculture vs. diversity" encompasses realizations about the connection between environmental integrity and food security. Proponents of agroecology have argued strenuously and provided substantial research supporting the idea that diversity in cropping systems does a better job than monocultures of retaining soil fertility and structure, pest biocontrol, water use, and other beneficial ecosystem services [7, 207, 226, 128]. There is well-accepted concern that food security depends on the integrity of ecosystem services for growing crops, and the "diversity" proponents propose harmonizing food production and maintenance of ecosystem services using biodiversity and low fossil-fuel inputs. On the "monoculture" side, some argue that diversification costs too much in labor for small farmers, and that the environment can be as well preserved by GIS-aided micromanagement of fertilizer and water systems for monocrops, provided they can be made available to small farmers. Which is better for maintaining the natural resource base for farming, what are the costs, and which is better for nutrition?

There are many unanswered questions brought out by the re-framing of the issue as "monoculture vs. diversity." Does crop diversity increase dietary diversity or not, does it help stabilize food security and income or not, does it help women or not, and does it help maintain the environmental resource base or not - and in all, does it affect nutrition.

6.1.2 Study aims

Based in a context where each of those issues is important, in Central Kenya and Northern Tanzania, the objectives of this study are:

1. to show whether on-farm crop diversity is related to greater food security and better diets, as measured by dietary diversity, fruit and vegetable consumption, and consumption of vitamin A-rich and iron-rich foods
2. to test whether any associations may operate through the home consumption or food purchase pathways
3. to present evidence about whether crop diversity may be related to women's status.

This study cannot begin to answer the questions of whether income from a diversity of crops is more or less sporadic than monocrops, nor the question of whether higher crop diversity better supports ecosystem services. The research was not designed to answer these questions, although they are important, and other research should work toward answering them.

6.1.3 Study sites and research setting

The research was conducted in Kiambu, Kenya, a district in Central Kenya that borders Nairobi, and Arusha, Tanzania, which surrounds Arusha town in northern Tanzania. The rural areas surrounding these cities are two areas of sub-Saharan Africa where each of the above-discussed questions about diversity is important: market opportunities, women's income-generating opportunities, seasonal food insecurity, avoidance of both over and under-nutrition, and the need for maintained or improved ecosystem services.

The study took place within the context of a program promoting production, marketing, and consumption of traditional African vegetables among small farmers in Kiambu, Kenya and Arusha, Tanzania. The Traditional Foods Project was designed and implemented as an income-generating program within the context of the dual burden of malnutrition . The goal of the program was to increase production and marketing of traditional African vegetables (TAVs) among small farmers, and to improve household income and nutrition. It was a three-year program implemented in both sites by the International Potato Center (CIP), the World Vegetable Center Regional Center for Africa (AVRDC-RCA), and Farm Concern International, a Kenyan non-profit organization.

6.2 Methods

6.2.1 Study design and data collection

Cross-sectional analyses of household survey data from two countries were used to examine the research questions. A survey of 169 households in four divisions of Kiambu, Kenya and 207 households in Arusha, Tanzania was carried out as part of an evaluation of an agricultural program promoting traditional African vegetables.

Approximately half of the sample were randomly selected from four communities (per country) not participating in the program, and half were selected on the basis of participation in the program, from four communities (per country) where the program was operatinng.

The survey was administered over a period of four to five weeks simultaneously in both sites, which ensured comparable seasonality. Teams of interviewers administered the questionnaire in the local language of respondents, which was Kikuyu in Kenya, and Kiswahili or occasionally Maasai in Tanzania. The survey took one to two hours to complete for each household, and collected data on household demographics, assets, income sources, agricultural production, household diet (including the source of foods consumed), and diet of children age 2-5 years.

There were one to two respondents for each household. The sections on agricultural production were administered to the person in the household mainly responsible for agriculture. The sections on diet were administered to the person mainly responsible for taking care of the reference child age 2-5 years (or if there was no child, the person responsible for the majority of the cooking in the household). The respondents were usually different (male and female, respectively) but were occasionally the same person.

6.2.2 Measurement of constructs

The main constructs measured for this study were diet quality and crop diversity. Source of foods consumed were also important for hypothesis testing.

Crop diversity was measured by asking the respondent responsible for the majority of agriculture in the household to free-list all crops that were grown in the last 12 months. Using a list of local crop names, interviewers were trained to probe about crops that had higher probabilities of being forgotten, such as fruit trees and semi-wild leafy vegetables. Total crop diversity was a count of all crops listed. Information on livestock-holding was also collected, and was used to create a total farm diversity indicator which included both plant and animal species.

Dietary quality was measured using several indicators based on a 24-hour food list recall and a 7-day validated food frequency questionnaire [219]. Source of foods consumed was obtained from the 7-day FFQ. The indicators calculated from the dietary data are listed in Table 6.1.

A food security indicator was also collected, measured as months of adequate household food provisioning [18].

Table 6.1: Construct measurement

Construct	**Definition and method**	**Range**
Dietary diversity score (household): HDDS	Count of 12 food groups consumed by anyone in the household in the 24 hours prior to the survey, using a 24-hr recall technique for generating a food list*	0 to 12
Dietary diversity score (individual child age 2-5 years): IDDS	Count of 8 food groups consumed by the child in the 24 hours prior to the survey, using a 24-hr recall technique for generating a food list**	0 to 8
Dietary variety score (household): HDVS	Count of all unique food items consumed in the household in the 24 hours prior to the survey, using a 24-hr recall technique	0 to ∞
Dietary variety score (individual child age 2-5 years): IDVS	Count of all unique food items the child consumed in the 24 hours prior to the survey, using a 24-hr recall technique	0 to ∞
Number of fruits and vegetables consumed	Count of number of fruits and vegetables consumed in the household in the 24 hours prior to the survey, using a 24-hr recall technique	0 to ∞
Number of vitamin A-rich foods consumed	Number of times food items containing $\geq$ 100μg RAE/100g were consumed in the last week, using HKI 7-day FFQ†[219]	0 to 70
Number of iron-rich foods consumed	Number of times food items containing $\geq$ 1mg iron per 100g were consumed in the last week, using HKI 7-day FFQ†[219]	0 to 70

Table 6.1 (continued)

Food purchase diversity score	Among the food groups that made up the HDDS, the number of food groups consumed in the last week which were obtained by food purchase, as measured by the 7-day FFQ	0 to 9††
Home produced food diversity score	Among the food groups that made up the HDDS, the number of food groups consumed in the last week which were obtained from home production, as measured by the 7-day FFQ	0 to 9††

*HDDS Food groups: cereals; roots/tubers; vegetables; fruits; meat/poultry; eggs; fish; pulses/nuts; milk/yogurt/cheese; oil/fat; sugar/honey; miscellaneous [253].

**IDDS Food groups: grains/roots/tubers; DGLV; other fruits and vegetables; meat/poultry/fish; eggs; pulses/nuts; milk; oil/fat [253].

†Because dark green leafy vegetables (DGLV) are often mixed together, they were not counted individually; the maximum days any one TAV was consumed and the maximum days any one other DGLV was consumed were used in the count of micronutrient-rich foods (2 numbers, one for each group; not 8, one for each individual DGLV in the FFQ).

††The maximum food purchase/home produced diversity score was 9 instead of 12 because the FFQ did not capture all possible foods and because foods not possible to grow on-farm were excluded. Grains/roots/tubers were combined into one group, fish (represented by dried anchovy) was combined with "other," and sugar/honey was excluded as a food group.

6.2.3 Data entry and statistical methods

Questionnaire data were double entered using CSPro data entry software [42], onto electronic forms that looked identical to the printed survey questionnaire.

Mixed models were run to test cross-sectional associations between crop diversity and dietary outcomes of interest, controlling for wealth and other potentially confounding covariates as fixed factors, and district and village as random factors to account for complex survey design. All terms in the model were tested for significant interactions with program group, to test if the different selection methods in program and non-program villages affected the relationships; if interaction terms were not significant, they were removed from the model.

There were some small but significant differences between the interviewers in the mean number of species they elicited from farmers, and also the mean number of foods that were counted to make up the dietary variety scores, although distribution was similar between interviewers. Therefore all analyses testing associations between crop diversity and dietary diversity or other indicators controlled for the interviewer as a fixed effect.

Logistic regressions were performed to test associations between crop diversity and consumption of each food group. All analyses were carried out in PASW/SPSS statistical software (version 18.0) [247].

6.2.4 Focus group discussions

Focus group discussions (FGD) were held as a part of the program evaluation, which contributed some useful information understand motivations for growing diversity and men's and women's roles and labor in farming. In Kiambu, 15 FGDs were held (5 women-only, 5 men-only, and 5 mixed gender), and in Arusha, 7 FGDs were held (2 women-only, 1 men-only, 4 mixed gender) before the survey was administered. The average number of participants in each group was 11. Participants were selected based on membership in a farmer group which was growing TAVs, and voluntary expression of interest to participate. The setting for each was usually in a central community meeting place such as a school, hall, or church, or sometimes in a community leader's home. Each FGD lasted approximately 30-60 minutes, and other topics not related to the research questions of this paper were covered in the discussion. Discussions were simultaneously interpreted between English and Kikuyu/Kiswahili by collaborators who were fluent in both languages and had extensive previous experience conducting FGDs for research. Information discussed was recorded as notes.

Focus group notes were reviewed and cleaned/clarified within 24 hours of the FGDs, and were then typed and coded. Notes were subsequently organized in a data spreadsheet (MS Excel) by code topic.

6.3 Results

6.3.1 Descriptive statistics

Among households surveyed, the total number of crops grown is close to 12 on average in Kiambu, and nine on average in Arusha (Table 6.2). Arusha households had more livestock species, however. Households in the survey were relatively homogenous with regard to livestock ownership, 77-80% owning at least one cow, 65-77% having chickens, and in Arusha, 65% also having at least one goat.

Table 6.2: On-farm diversity

	Kiambu, Kenya n = 169)	**Arusha, Tanzania** (n = 207)
Total number of crops grown (mean, s.d.)	11.75 (4.65)	8.76 (4.20)
Total number of livestock species (mean, s.d.)	1.86 (0.95)	2.61 (1.16)
% of households with a cow	79.8	76.7
% of households with a chicken or duck	65.1	76.3
% of households with a goat	8.7	64.9
Total farm diversity: crops and livestock species (mean, s.d.)	13.61 (5.10)	11.38 (4.45)

Household dietary diversity was between 7-8 food groups on average, and 14 distinct foods/ingredients were consumed on average in Kiambu, 12 distinct foods/ingredients in Arusha (see Table 6.3). Diets among pre-school age children (age 2-5 years) were very similar to household diets. Slightly fewer fruits and vegetables, and vitamin A-rich foods, were consumed per day in Arusha than Kiambu, and households in Arusha experienced on average twice the number of months of food insecurity (inadequate food as perceived by the household) as Kiambu (four vs. two months).

Table 6.3: Dietary indicators

	Kiambu, Kenya (n = 169)	**Arusha, Tanzania** (n = 207)
HDDS* (max=12) (Dietary diversity score= number of food groups)	7.80 (1.22)	7.31 (1.27)
IDDS** (max=8) (individual child dietary diversity score)	5.64 (0.81)	5.54 (0.84)
HDVS (Household dietary variety score= number of unique foods)	14.03 (3.56)	11.43 (2.62)
IDVS (Individual child dietary variety score)	14.01 (3.29)	11.21 (2.61)
Fruit and vegetables consumed (number in the last 24 hours)	5.18 (2.11)	3.58 (1.55)
Frequency of vitamin A-rich foods consumed in 1 week (max=70)	15.46 (6.41)	11.95 (6.04)
Frequency of iron-rich foods consumed in 1 week (max=70)	18.15 (6.34)	19.99 (7.44)
Months of inadequate food in the last year	1.97 (2.02)	3.88 (1.73)

*HDDS 12 Food groups: cereals; roots/tubers; vegetables; fruits; meat/poultry; eggs; fish; pulses/nuts; milk/yogurt/cheese; oil/fat; sugar/honey; miscellaneous. **IDDS 8 Food groups: grains/roots/tubers; DGLV; other fruits and vegetables; meat/poultry/fish; eggs; pulses/nuts; milk; oil/fat.

In each site, roughly half of food items in the FFQ were sourced from purchase (see Figures 6.1 and 6.2). A small proportion of food came from wild collection and other sources. It is important to note that these results do not capture *all* foods consumed by the household, but rather they summarize the 33 food items in the FFQ. The 33-item FFQ was pre-tested and included most foods typically consumed in the study sites, but it did not list many foods that could have been collected from wild sources. Therefore, the food purchase and home consumption percentages probably closely represent the true sources of the complete household diet, but wild-collection is probably underestimated from the survey tool used.

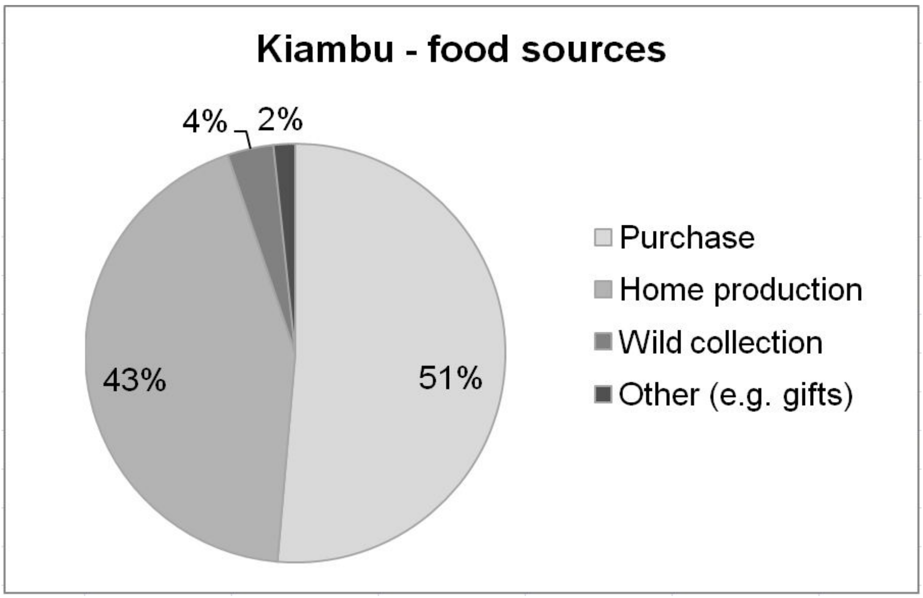


Figure 6.1: Food sources - percent of the number of foods consumed by source, Kiambu

Table 6.4 shows the descriptive statistics for home production and food purchase diversity. A greater diversity of foods were purchased than home produced. In Kiambu, more fruits and vegetables were sourced from home production than purchase, and in Arusha, it was the opposite.

6.3.2 Months of food security and crop diversity

The results listed here show the relationship between reported months of food security and number of crops grown. The hypothesis for how diversity of crops would relate to food security is through more consistent availability of crops to

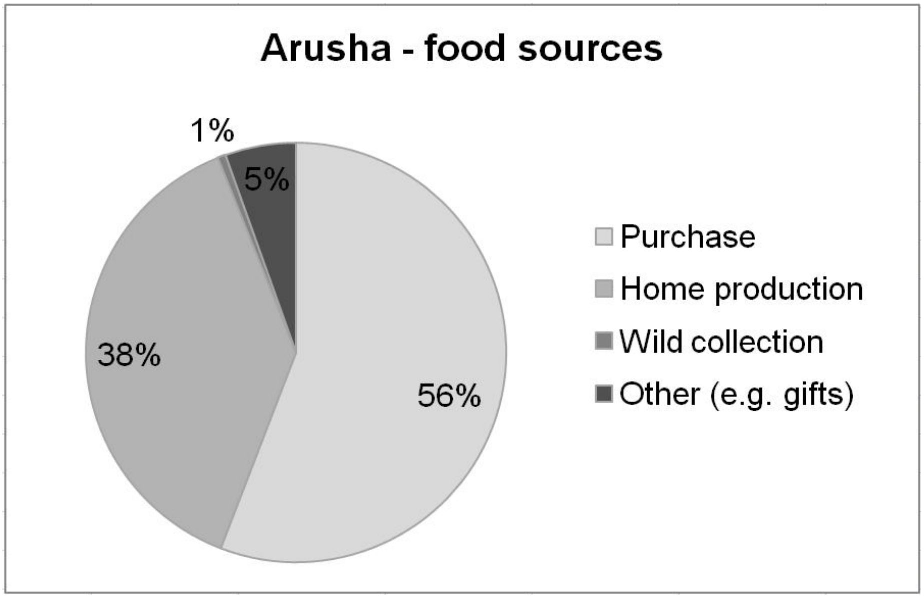


Figure 6.2: Food sources - percent of the number of foods consumed by source, Arusha

Table 6.4: Sources of dietary diversity: home production and purchase

	Kiambu, Kenya (n = 169)	**Arusha, Tanzania (n = 207)**
Home-produced diversity score (max 9)*	3.03 (1.42)	3.45 (1.68)
Food purchase diversity score (max 9)†	5.77 (1.49)	5.45 (1.65)
Number of fruits and vegetables consumed from home production	3.63 (1.89)	1.44 (1.58)
Number of fruits and vegetables consumed from purchase	2.47 (1.42)	2.98 (1.77)

*Food groups: cereals/roots/tubers; vegetables; fruits; meat/poultry; eggs; pulses/nuts; milk/yogurt/cheese; misc (including small fish)
†Food groups: cereals/roots/tubers; vegetables; fruits; meat/poultry; eggs; pulses/nuts; milk/yogurt/cheese; misc (including small fish); oil/fat

harvest and consume, and/or a consistent supply of crops to sell throughout the year, to make income flow more continuous.

The cross-sectional analysis model predicting months of food security based on crop diversity controlled for enumerator, wealth, household size, age of household head, land access, and program group.

When other measured variables were held constant, there was no significant association between crop diversity and months of food security in either site.

6.3.3 Dietary diversity and crop diversity

In Kiambu, crop diversity was significantly positively associated with dietary variety (HDVS); each crop grown was associated with 0.2 additional foods consumed (Table 6.5). In the model predicting child dietary variety (IDVS), crop diversity was not significant; but because children ate almost exactly the same foods as the household as a whole, the lack of significance probably is due to a much smaller sample size of children than of households in Kiambu. The models predicting household and individual dietary diversity scores were not significant. Dietary diversity may not have been variable enough in Kiambu to predict well; 79% of households consumed 7-9 food groups (out of 12), and 84% of children consumed 5-6 food groups (out of 8).

In Arusha, crop diversity was significantly positively associated with both household and child dietary diversity and dietary variety, controlling for the socioeconomic status indicators of wealth, land size, household age and caretaker's education (Table 6.6).

6.3.4 Is it crops or livestock that make the difference?

Previous research in international nutrition concludes that it is animal-source foods available to the household that makes a difference to diet quality in developing countries, not plant-source foods [5, 48]. (Although it is more often diversity and quantity of plant source foods that are recommended to make a difference in improving diets in developed countries [278].) This research could also test the

Table 6.5: Predictors of dietary diversity and dietary variety, Kiambu, Kenya

	Model 1		Model 2		Model 3		Model 4	
	Dietary diversity (HDDS)		Household dietary variety (HDVS)		Child dietary diversity (IDDS)		Child dietary variety (IDVS)	
	n=167		n=167		n=87		n=87	
	Est. [S.E.]	Sig.	Est. [S.E.]	Sig.	Est. [S.E.]	Sig.	Est. [S.E.]	Sig.
Crop diversity (# crops grown)	0.027 [0.024]	0.260	0.171 [0.067]	0.011	NS		0.081 [0.099]	0.413
Wealth (log value of assets owned)	0.155 [0.094]	0.101	0.341 [0.255]	0.183	NS		0.039 [0.384]	0.891
Household size	0.013 [0.054]	0.808	0.076 [0.147]	0.607	NS		-0.135 [0.232]	0.561
Age of household head (years)	-0.007 [0.008]	0.430	-0.032 [0.022]	0.157	NS		-0.033 [0.029]	0.246
Caretaker's education (years)	0.054 [0.030]	0.074	0.227 [0.082]	0.006	NS		0.162 [0.120]	0.180
Land access (acres)	0.036 [0.059]	0.546	-0.109 [0.164]	0.507	NS		0.884 [0.286]	0.003
Program participation	-0.372 [0.235]	0.160	-0.192 [0.882]	0.834	NS		0.811 [1.077]	0.485

Note: Models also controlled for enumerator as a fixed effect, and district and village as random effects.

question of whether farm diversity in total, rather than crop diversity, be a better indicator related to diet. Since livestock are more important in farming systems in Arusha than Kiambu, comparisons between models using crop diversity vs. farm diversity are presented only for Arusha in Table 6.7, although the comparison tells the same story in Kiambu as well. Crop diversity, rather than livestock presence or diversity, appears to be the factor related to dietary diversity and variety in this population. Livestock ownership may be important to household nutrition

Table 6.6: Predictors of dietary diversity and dietary variety, Arusha, Tanzania

	Model 1		Model 2		Model 3		Model 4	
	Dietary diversity (HDDS)		Household dietary variety (HDVS)		Child dietary diversity (IDDS)		Child dietary variety (IDVS)	
	n=201		n=201		n=165		n=165	
	Est. [S.E.]	Sig.	Est. [S.E.]	Sig.	Est. [S.E.]	Sig.	Est. [S.E.]	Sig.
Crop diversity (# crops grown)	0.067 [0.027]	0.012	0.141 [0.054]	0.010	0.049 [0.020]	0.016	0.165 [0.062]	0.009
Wealth (log value of assets owned)	-0.019 [0.068]	0.784	-0.021 [0.137]	0.879	0.012 [0.054]	0.826	0.080 [0.155]	0.606
Household size	0.003 [0.036]	0.931	0.014 [0.072]	0.847	-0.016 [0.027]	0.552	-0.008 [0.080]	0.920
Age of house-hold head (years)	0.018 [0.009]	0.041	0.015 [0.018]	0.379	0.000 [0.007]	0.994	-0.002 [0.020]	0.928
Caretaker's education (years)	0.130 [0.033]	<0.001	0.254 [0.064]	<0.001	0.058 [0.024]	0.018	0.251 [0.071]	0.001
Land access (acres)	0.180 [0.019]	0.352	0.018 [0.040]	0.651	0.010 [0.019]	0.600	-0.030 [0.057]	0.605
Program participation	0.321 [0.269]	0.272	0.301 [0.360]	0.405	-0.015 [0.134]	0.908	0.240 [0.390]	0.540

Note: Models also controlled for enumerator as a fixed effect, and district and village as random effects.

by contributing milk and eggs in particular, but almost all households had some livestock (most had both a cow and chickens), so livestock ownership or diversity may not have been variable enough in this sample to show any relationship to diet. It also did not make a difference to analyses if livestock, cows, or chickens were included as bivariate indicators. In no analysis did total farm diversity have a stronger or different relationship with dietary outcomes than crop diversity.

Table 6.7: Difference between models with crop diversity or farm diversity (crops and animal species), Arusha, Tanzania

	Model 1		Model 2		Model 3	
	Household dietary variety (HDVS)		Household dietary variety (HDVS)		Household dietary variety (HDVS)	
	Est. [S.E.]	p-value	Est. [S.E.]	p-value	Est. [S.E.]	p-value
Crop diversity (# crops grown)	0.141 [0.054]	0.010	-	-	-	-
Farm diversity (# crops grown and livestock species)	-	-	0.125 [0.051]	0.015	-	-
Livestock diversity (# livestock species)	-	-	-	-	0.020 [0.192]	0.916

Note: Models also controlled for wealth, household size, headage, caretaker education, land access, program group; the parameter estimates were very similar in both magnitude and significance in all three models, so they are not presented here. Models also controlled for enumerator as a fixed effect, and district and village as random effects.

6.3.5 Consumption of specific food groups and crop diversity

Consistent associations between crop diversity and indicators of diet quality were seen in both Kiambu and Arusha, where crop diversity was significantly correlated with number of servings of vitamin A-rich foods, iron-rich foods, and fruits and vegetables in both countries (Tables 6.8 and 6.9). (Statistical significance was marginal for the association between crop diversity and vitamin A-rich food consumption in Arusha; p=0.06.)

Logistic regressions were performed to test the association of crop diversity with odds of eating each individual food group: roots/tubers, fruits, meat/poultry, eggs, fish, pulses/nuts. Associations between crop diversity and grains, vegetables, milk,

Table 6.8: Predictors of consumption of vitamin A-rich foods, iron-rich foods, and fruits and vegetables, Kiambu, Kenya

	Model 1		Model 2		Model 3	
	No. of servings of vitamin A-rich foods		No. of servings of iron-rich foods		No. of fruits and vegetables consumed	
	n=167		n=167		n=167	
	Est. [S.E.]	p-value	Est. [S.E.]	p-value	Est. [S.E.]	p-value
Crop diversity (# crops grown)	0.304 [0.123]	0.015	0.479 [0.169]	0.005	0.143 [0.040]	<0.001
Wealth (log value of assets owned)	0.386 [0.479]	0.421	0.433 [0.684]	0.528	0.046 [0.154]	0.763
Household size	0.031 [0.273]	0.909	1.226 [0.487]	0.013	0.100 [0.089]	0.262
Age of household head (years)	-0.013 [0.042]	0.760	-0.067 [0.061]	0.270	-0.007 [0.014]	0.622
Caretaker's education (years)	0.419 [0.152]	0.007	0.702 [0.282]	0.014	0.096 [0.049]	0.053
Land access (acres)	0.145 [0.300]	0.630	0.286 [0.432]	0.509	-0.170 [0.099]	0.089
Program participation	0.920 [1.063]	0.388	-15.066	0.009	0.081 [0.543]	0.886
(Household size × Program group) interaction	-	-	1.898 [0.782]	0.016	-	-
(Caretaker education × Program group) interaction	-	-	1.126 [0.390]	0.004	-	-

Note: Models controlled for enumerator as a fixed effect, and district and village as random effects.

oil, sugar, and miscellaneous items (e.g. tea) could not be performed because consumption of those food groups was either 100% or very close to 100%. The regressions controlled for wealth, household size, age of household head, caretaker's

Table 6.9: Predictors of consumption of vitamin A-rich foods, iron-rich foods, and fruits and vegetables, Arusha, Tanzania

	Model 1		Model 2		Model 3	
	No. of servings of vitamin A-rich foods		No. of servings of iron-rich foods		No. of fruits and vegetables consumed	
	n=201		n=201		n=201	
	Est. [S.E.]	p-value	Est. [S.E.]	p-value	Est. [S.E.]	p-value
Crop diversity (# crops grown)	0.240 [0.128]	0.062	0.653 [0.189]	0.001	0.100 [0.032]	0.002
Wealth (log value of assets owned)	0.046 [0.323]	0.888	-0.545 [0.522]	0.298	0.004 [0.081]	0.961
Household size	0.041 [0.170]	0.812	0.118 [0.271]	0.664	-0.015 [0.042]	0.728
Age of household head (years)	-0.009 [0.041]	0.834	-0.020 [0.067]	0.770	-0.011 [0.010]	0.285
Caretaker's education (years)	0.229 [0.151]	0.133	-0.315 [0.243]	0.196	0.072 [0.038]	0.058
Land access (acres)	-0.003 [0.094]	0.974	0.021 [0.144]	0.886	-0.002 [0.024]	0.925
Program participation	1.726 [0.865]	0.133	1.390 [1.368]	0.311	0.394 [0.212]	0.065

Note: Models also controlled for enumerator as a fixed effect, and district and village as random effects.

education, land size, and program group.

Each additional crop was associated with an 18% increased chance of having eaten fruit in the last 24 hours in Arusha ($p<0.001$). Each additional crop was also associated with a 14% increased chance of eating eggs in Kiambu ($p<0.001$), and a 42% increased chance of eating eggs in Arusha ($p=0.002$). (Caretaker's education was the only other factor significantly positively associated with eating eggs in Kiambu.) The significance of these associations remains even with a Bonferroni adjustment for multiple comparisons: the same test was done for six different food groups, so $p<0.008$ can be considered significant. There were no significant associations between crop diversity and odds of consuming any other food group.

It is expected that increased crop diversity should be associated with increased likelihood of eating fruit. One might also expect it to be associated with increased odds of vegetable consumption; the reason that association was not shown is because over 95% of households consumed vegetables in both countries. It was less expected that increased crop diversity would be associated with egg consumption. The association was unchanged even after controlling for chicken ownership. One explanation is that farmers with more crops may have more diversified income sources, so that they do not feel obliged to sell all of their eggs. Farmers with more crops also may have more available income to purchase eggs at any given time, particularly if women control small amounts of income from the sale of minor crops.

6.3.6 Direct home consumption or food purchase pathway

If more crops are produced, dietary variety and diversity may be affected via two pathways: direct home consumption of more crops produced or by greater income from the crops facilitating greater variety of food purchases.

To test the hypothesis that crop diversity is related to dietary diversity primarily through the home-consumption pathway in this population, the data were analyzed to answer (1) whether crop diversity correlates better with consumed foods that were home-produced, or with foods that were purchased, and (2) whether higher crop diversity correlates with a higher percentage of foods sourced from home production.

With the available data, these tests were a better way to approach the question of how crop diversity may operate to affect diet than is examining the correlation between crop diversity and income. The measure of income available from this survey was only a proxy - it captured socioeconomic status overall, but did not capture actual cash or in-kind income. More importantly, the causal direction is uncertain - do people with a lot of assets diversify their crops, or do more diverse crops lead to higher income? That is a central question having to do with diversity, and it cannot be answered by this study directly.

Tables 6.10 and 6.11 show that as number of crops cultivated increases by 1, the number of food groups consumed that were obtained through own-farm production increases by 0.1 in Arusha ($p<0.001$); or, as number of species increases by 10, it is probable that food groups consumed from own-farm production increases by 1. The same association was marginally significant in Kiambu ($p=0.076$). In both countries, crop diversity was strongly related to home-produced fruit and vegetable variety consumed ($p<0.001$). Crop diversity as related to self-sufficiency of food production shows evidence for the direct home consumption pathway.

There was no significant relationship between the number of crops produced and the number of food groups purchased.[1] This finding indicates that all else equal, people purchase the same type of foods no matter what they produce on the farm, but farmers who produce a greater variety of foods consume a greater variety of foods from home production.

As the number of crops produced increases, the percent of food items consumed that were obtained from home production increases in a highly significant direct relationship in both countries (Figures 6.3 and 6.4, and Table 6.12). Each additional crop grown is associated with a 0.7-0.9 percentage point increase in the percentage of foods sourced from home production. Figures 6.3 and 6.4 show the relationship graphically. These figures show that farmers consume what they grow,

[1]As mentioned above, only foods that could be produced on farm were included in the food purchase diversity score and the home produced diversity score.

Table 6.10: Predictors of dietary diversity and dietary variety, Kiambu, Kenya (n=167)

	Model 1		Model 2		Model 3		Model 4	
	Home-produced diversity score		Home-produced fruit and veg variety		Purchased diversity score		Purchased fruit and veg variety	
	Est. [S.E.]	Sig.	Est. [S.E.]	Sig.	Est. [S.E.]	Sig.	Est. [S.E.]	Sig.
Crop diversity (# crops grown)	0.044 [0.024]	0.076	0.141 [0.028]	<0.001	-0.003 [0.028]	0.903	-0.052 [0.026]	0.044
Wealth (log value of assets owned)	0.432 [0.093]	<0.001	0.325 [0.107]	0.003		0.275	-0.123 [0.096]	0.201
Household size	-0.077 [0.053]	0.150	0.152 [0.077]	0.050		0.498	-0.108 [0.069]	0.124
Age of household head (years)	0.007 [0.008]	0.368	-0.016 [0.009]	0.091	-0.023 [0.009]	0.014	-0.006 [0.008]	0.495
Caretaker's education (years)	0.041 [0.030]	0.168	-0.009 [0.034]	0.785		0.106	0.082 [0.031]	0.009
Land access (acres)	-0.061 [0.059]	0.297	0.037 [0.068]	0.590		0.684	0.023 [0.061]	0.707
Program participation	0.422 [0.221]	0.112	0.726 [0.684]	0.296		0.430	1.207 [0.601]	0.048
(Household size $\times$ Program group) interaction	-	-	0.367 [0.121]	0.003	-	-	-0.318 [0.109]	0.004

Note: Models also controlled for enumerator as a fixed effect, and district and village as random effects.

in general. In this population, when people grow another crop, they do not just sell it - farmers who grow more crops are more self-sufficient (rely more on own-farm

Table 6.11: Predictors of dietary diversity and dietary variety Arusha, Tanzania (n=201)

	Model 1		Model 2		Model 3		Model 4	
	Home-produced diversity score		Home-produced fruit and veg variety		Purchased diversity score		Purchased fruit and veg variety	
	Est. [S.E.]	Sig.	Est. [S.E.]	Sig.	Est. [S.E.]	Sig.	Est. [S.E.]	Sig.
Crop diversity (# crops grown)	0.105 [0.032]	0.001	0.181 [0.029]	<0.001	0.028 [0.036]	0.433	-0.015 [0.039]	0.694
Wealth (log value of assets owned)	0.305 [0.087]	0.001	0.042 [0.071]	0.556		0.081		0.697
Household size	0.042 [0.045]	0.354	-0.005 [0.037]	0.890		0.346		0.593
Age of household head (years)	0.017 [0.011]	0.135	0.005 [0.009]	0.598		0.367		0.300
Caretaker's education (years)	0.080 [0.040]	0.050	0.098 [0.041]	0.018		0.413		0.092
Land access (acres)	0.006 [0.024]	0.820	-0.019 [0.020]	0.358		0.748		0.533
Program participation	0.375 [0.228]	0.102	-0.770 [0.519]	0.151		0.997		0.495
(Caretaker education × Program group) interaction	-	-	0.156 [0.070]	0.027	-	-	-	-

Note: Models also controlled for enumerator as a fixed effect, and district and village as random effects.

production) rather than less. This finding is strongly supported by qualitative data and field observations, where farmers said that in general, they consume whatever they grow, and that growing food saves them the trouble of having to go out and buy food. That is particularly important as it connects to women's work.

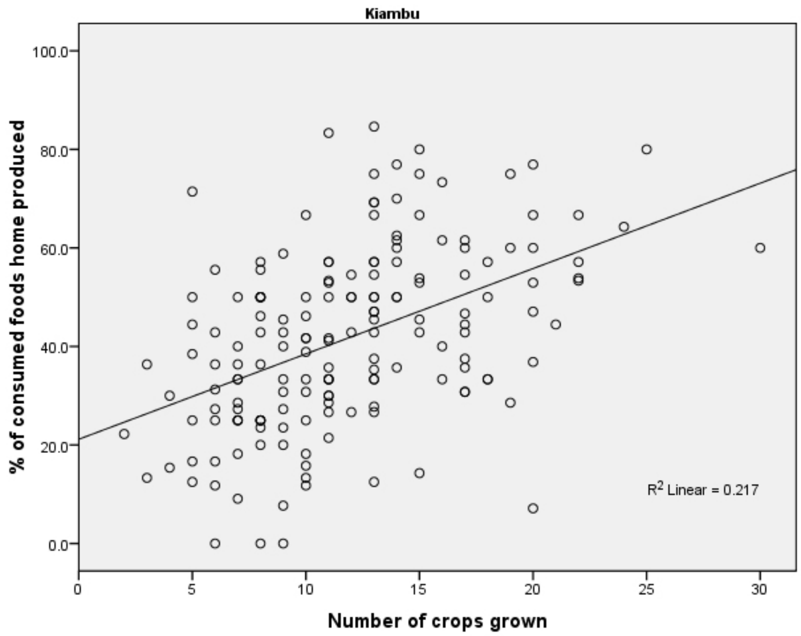


Figure 6.3: Relationship (unadjusted) between the number of crops grown and the percent of foods consumed in the last week that were sourced from home production (Kiambu, Kenya)

6.3.7 Relationship of crop diversity to women's well-being

Increased on-farm diversity may be risky for women because it could potentially increase workload for already overworked women. While this study did not assess time use and workload associated with traditional vegetable production compared to other crops, there are two questions to this argument: does increased diversity actually increase workload, and is increased workload necessarily bad.

1. Is diversification - particularly vegetable cultivation - more work for women?

In many cases, adding a crop to the farm that would be controlled by women may increase women's workload, assuming that their work on other male- or jointly-controlled crops remains the same, and a new minor crop is solely the women's responsibility.

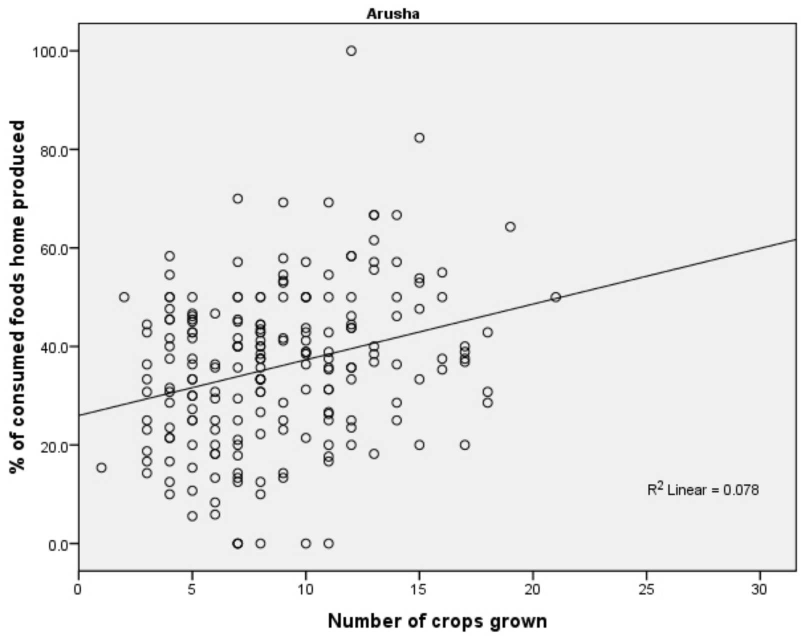


Figure 6.4: Relationship (unadjusted) between the number of crops grown and the percent of foods consumed in the last week that were sourced from home production (Arusha, Tanzania)

The qualitative results from this study do not clearly show information that increased vegetable crop production necessarily increases women's workload; in fact, they indicate the opposite.

In the case of TAVs, many women reported a major reason they grew TAVs was to decrease workload. There were many quotes along the lines of, "We grow them ourselves - it reduces the time the family spends looking for vegetables." The all-men focus groups shared the same information: "Wives don't go far to look for vegetables because they produce them right here. Also the market is far." It was nearly always the women's responsibility to prepare food for the household, purchasing whatever was needed that was not available on-farm. Vegetables were an important part of a complete meal, particularly when no meat could be accessed, so women were responsible for either gathering or purchasing vegetables. If they had vegetables constantly available on their own farm, it saved them considerable

Table 6.12: Predictors of the percent of foods sourced from home consumption

	Kiambu (n=167)		Arusha (n=201)	
	Percent of foods consumed sourced from home consumption			
	Est. [S.E.]	Sig.	Est. [S.E.]	Sig.
Crop diversity (# crops grown)	0.677 [0.288]	0.020	0.861 [0.325]	0.009
Wealth (log value of assets owned)	4.554 [1.084]	<0.001	2.433 [0.837]	0.004
Household size	-0.773 [0.622]	0.216	0.084 [0.440]	0.849
Age of household head (years)	0.058 [0.095]	0.545	0.338 [0.107]	0.002
Caretaker's education (years)	-0.221 [0.348]	0.525	1.005 [0.403]	0.014
Land access (acres)	-0.427 [0.692]	0.538	0.126 [0.237]	0.594
Program participation	10.841 [2.981]	0.027	3.960 [3.169]	0.260

Note: Models also controlled for enumerator as a fixed effect, and district and village as random effects.

time in either going out to gather wild vegetables (common in Arusha) or to go to market to purchase vegetables (common in both countries). Participants cited this time-saving aspect to growing TAVs time and time again as a reason why they grew them.[2]

Quantitative survey data shed some light on the issue of time-saving. Only 12% of households in Kiambu and 1% of households in Arusha had a refrigerator at the time of the interview, illustrating the difficulty of storing fresh leafy vegetables. Another useful piece of information is that households that sold vegetables reported that their main market was 35 km from their farm on average in Kiambu, and 6 km

[2]Note that in these sites, unlike some parts of Africa, households almost always lived on the same land as their own farm. The situation may be very different where the household farm is several kilometers away.

from their farm on average in Arusha. Women seldom went to their main market to purchase food - as indicated by focus group discussions, they often purchased items with a long shelf-life at such markets, and more perishable items at small markets closer to home. The statistic, however, indicates how going to market might be time-intensive, especially when the majority of women get to these markets by a combination of walking and public transport (in Kiambu), or simply walking (Arusha).

It may be that growing perishable crops such as green leafy vegetables is more important to women's time and household diet than even legumes, because legumes can be bought and stored. Due to the lack of refrigeration, getting vegetables and fruits, if not grown, requires adding a daily chore of getting to the market or wild-gathering. If markets are far, this is a substantial burden for women's time, and if they do not find the time to get to the market, it is a burden for household dietary diversity.

At the same time, farmers recognized the significant amount of labor involved in sowing TAVs. Of those who did not grow TAVs, a few commented that they did not grow them because of lack of labor, time, or being ill. It is not clear whether the lack of time to grow TAVs was specific to TAVs or referred to vegetables in general.

It is questionable, from the qualitative data collected, that growing TAVs increased the time-labor burden on women. What appeared to be the most prohibitive labor cost of TAV production was new marketing strategies to get higher prices: the main goal of the program under which this study was conducted. Farmers generally received lower prices selling TAVs to traders independently at the farmgate than if they took them to market, but they were willing to accept lower prices in exchange for not having to spend a day at the market to sell them at retail price. Market stall fees were another barrier to independent retailing. The TF project aimed to allow farmers to access better prices while still not having to personally go to market to sit and sell the TAVs all day, by organizing "commercial village" cooperatives. This, too, however, required time and energy to coordinate, which many farmers were not willing (at least initially) to devote to the prospect of better sales through group marketing.

2. ***If*** **diversification creates more work, is that bad for women?**

It is often assumed that any increased workload for women is bad for women. The reasons for this assumption are that women farmers in developing countries tend to work extraordinarily hard from sunrise to sunset, as the primary farm laborers as well as the cook and child caretaker for the household. Over-stretched as they are, it would be easy to assume that additional work (or time in group meetings) would be universally bad.

In interviews and focus group discussions in the research sites, farmers said that men are primarily interested in large commodities that often have large, lump-sum payments, such as maize, dairy, and tea, while women "prefer" (from the men's point of view) or, "are able to control" (from the women's point of view) minor crops with piecemeal harvests and small pay-offs. Both men and women focus groups independently verbalized that norm. As one respondent said it, "Men don't do much else besides farming for getting money. Farming for sustainability purpose, not for commercial, that's what women control." One farmer explained men's disinterest in minor, piecemeal crops by translating a Kikuyu saying into English: "So little buys so little." For the individual reciting the proverb, the meaning was that it was not worthwhile to spend time on small projects that would not result in much cash. Women, however, made several statements in focus groups such as, "The income is not much, but it helps to buy household items like soap." Meaning that even a small amount of new income enabled the women to purchase something needed in the household, which previously they may have had to ask their husbands for money to buy. Both men and women agreed that women having at least a small source of income was a benefit: the women could purchase what was needed for the household, without asking permission or bothering their husbands about it. The men indicated that they did not like frequent requests for petty cash from their wives, and the women indicated that they did not like making those requests - which adds up to evidence that women requesting money from men for household items was a source of mutual annoyance and conflict.

The main insight from these observations is that women are unlikely to control income if a farm only produces one or two large commodities. Commodities (maize, milk, tea) were almost universally controlled by men, and if women had no other steady income source, the dramas of income exchange and bargaining were bound to ensue [2]. More diverse farms, however, provide greater opportunities for women to control income from their own labor and at the point of sale, avoiding some of the intra-household bargaining for household necessities and reducing barriers to their purchase. This was particularly the case with crops that could be harvested piecemeal and sold at small scale. The conclusion from this study is that while more diverse farms may or may not increase labor requirements of women (this was not measured), women likely have more opportunities to benefit financially from more diverse farms.

Income control of minor crops

It would have been interesting to measure the relationship between diversity and the amount of income women control for daily household needs; however, the survey did not capture that data.[3]

The survey did measure women's control of traditional vegetable crops in particular, and found that women almost always make the decisions about planting, are mainly responsible for the crop production, for taking the crop to market, and control 60% of the income from the traditional vegetables in Kiambu, 63% in Arusha. This supports the qualitative data that women mainly control minor crops, if other minor crops show similar patterns to TAVs.

The hypothesis that more frequent harvesting of TAVs was associated with greater women's income control, and that large harvests would be more associated with lump-sum payments and male control, was tested. The results could imply lessons of greater applicability to farm diversity: if crops are grown which can be harvested piecemeal, women may be able to control more income. The results, however, show no association between number of traditional vegetable harvests and women's income control when controlling for amount harvested. Greater *total* harvest amounts were more likely to be under men's control, no matter how frequently the crops were harvested (See Figures 6.5 and 6.6). These results indicate that some combination of *the crop identity* and *the amount grown*, rather than whether it is harvested piecemeal or at once, are more strongly associated with women's income control.

Cost-benefit analysis of diversity from the woman's point of view

Whether additional crops are a benefit or a harm depends on who decides to plant them, how much is planted, whether or not they require more work on the whole, and if they do, who benefits from that labor. In the case of maize, for example,

[3]The measure of decision-making power used in the survey, having to do with major new purchases, sought to capture overall balance of power between the genders and was not specific enough to capture the effect of small, frequent income on household decisions. In retrospect, we should have asked "Do you ask your husband for small cash to buy household necessities, or do you have the cash on your own, (or some of each)?"

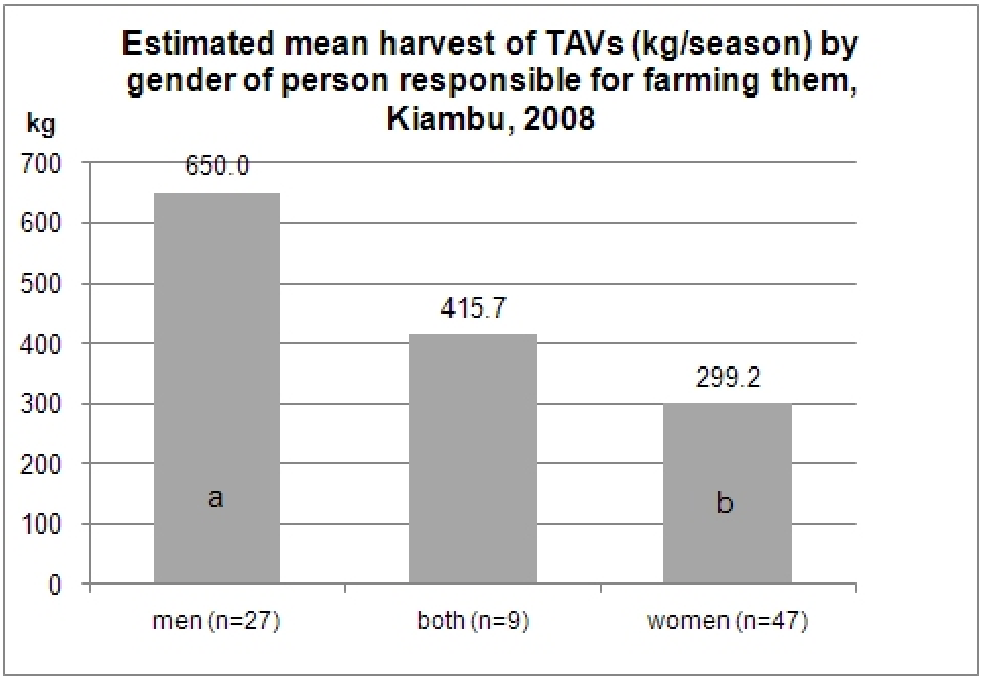


Figure 6.5: Harvest by gender, Kiambu

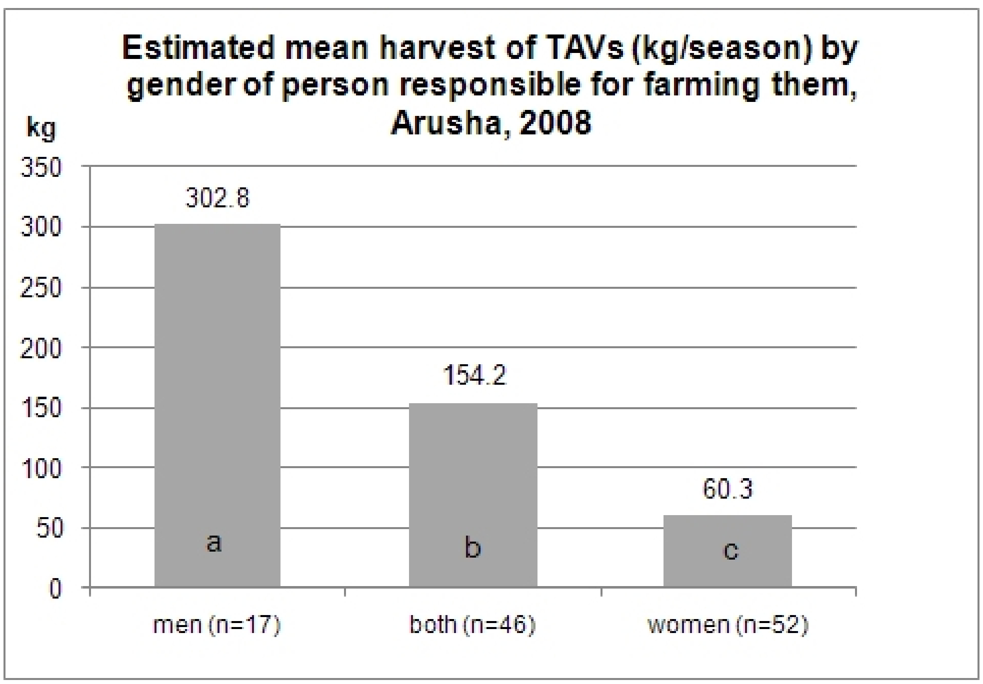


Figure 6.6: Harvest by gender, Arusha

men typically control production and sale in these study sites, although women typically do the weeding. If a new variety of maize were introduced which required more weeding, women would do extra work while men would still control the crop sale, so women may or may not witness any benefit to the household, and may realize only the cost of increased labor. In contrast, in the case of leafy vegetables, women typically decide whether or not they will plant them, and they control the production and sale to a large extent. If a new traditional vegetable were planted, women may do all or almost all the work to produce it, but they may also realize the majority of the benefit of that labor. Whether women themselves decide on the new endeavor or if the work is imposed is very important for the cost-benefit analysis of minor crops production. The benefits women may expect to receive are not limited to cash income received from sale; they also include obviation of the need to buy vegetables (saving income), reduction of work to collect TAVs from the wild or to walk to the market to purchase TAVs, and non-monetary benefits of personal empowerment, and in some cases respect from their husbands, for having some income of their own, particularly if the woman uses it for the betterment of the household.[4]

Additional work for women is not necessarily harmful. It depends heavily on whether there are net benefits from the output of her additional work, and who controls those benefits.[5]

6.3.8 Motivation to cultivate diversity

Information from focus group discussions and interviews revealed that marketing potential, need for home use, and income security were all important reasons for

[4] In some cases, unfortunately, domestic violence could also be a consequence of increased women's independence or income control. In a women-only focus group discussion in Arusha region, one woman reported that she did not participate actively in TF Project meetings because she feared that some men in the group would tell her husband she was acting independently, the consequences of which she feared.

[5] An important aspect to keep in mind is whether the increased labor is physically demanding or primarily only time-intensive; heavy physical demands can carry a special risk of hazard, since it may place an already over-extended woman into increased risk of malnutrition.

choosing to grow several crops. Some farmers also discussed the need for crop rotation to avoid serious pest and pathogen problems. Overall women seemed to have a substantial say in the crops planted particularly in Kiambu.

6.4 Discussion

The associations observed in this study seem to indicate that as more kinds of crops are cultivated in these smallholder households, the household is more likely to consume a greater diversity of foods, including nutrient dense foods and fruits and vegetables. These associations were observed in both sites. In Tanzania only, where access to market was more limited, crop diversity was also associated with consumption of more diverse food groups. The associations appeared to operate primarily through home consumption of own-farm produced crops rather than increased diversity of food purchases.

As for how crop diversity might affect women, it may create more work (unknown), but the work may be chosen by the women themselves if it saves daily time and effort of going to market to purchase daily food needs. Increased in income generating opportunities for women appear to be inaccessible if the farm only produces large-volume commodities.

6.4.1 Study limitations

Cross-sectional analysis takes advantage of between-household variability, rather than looking for within-household changes over one year which would be much smaller. An inherent limitation of cross-sectional analyses, though, is the possibility of residual confounding. The analyses attempted to identify and control for major confounding variables such as wealth, land access, and education. It is possible that the models still suffer from omitted (mostly unmeasurable) variables.

While almost half the sample was chosen randomly, the other half chosen based on their participation in an agricultural marketing program. That the sample of households in these analyses was not entirely randomly chosen could present selection bias. The primary factor associated with participation in the program was growing TAVs. It is possible that either growing TAVs or propensity to join an agricultural marketing program represents a household characteristic that makes this sample less generalizable to a completely random sample. However, where models tested interactions between each term and program participation, there were rarely any significant interactions, and those that were significant were controlled for. This increases confidence that the households sampled from program villages behaved similarly to households chosen at random from comparison villages.

Crude measurement of farm diversity hampered this analysis and probably attenuated the results. The study would probably have been stronger if the true diversity (measured by a farm survey) could have been used as an indicator, rather than the diversity reported, dependent on the enumerator who took the measurement. (In this study, analyses controlled for enumerator to minimize the influence of interviewer bias.) Different recall periods for crop diversity (one year), and dietary diversity (24-hrs), and home produced food diversity (one week) probably reduce the strength of associations. It would have been good to collect data on the crops the farmer had growing in their fields on the day of the survey. However, since strong associations were seen, reducing misclassification by harmonizing recall periods would probably only increase the strength of associations.

6.4.2 Conclusions

This study is novel for several reasons. It is one of the few to link dietary diversity and crop diversity. The indicators of home-consumed food diversity score and food purchase diversity score were created in this study, and have not been seen elsewhere. Longitudinal research would be helpful to test if these associations hold over time. Additional research into the relationship between diversity and women's status, work, and income generating opportunities is needed.

Results point to caution for agricultural interventions that promote only one or few commodity crops. Such interventions could miss opportunities or cause harm by limiting home consumption, particularly where markets are far and time is scarce. Calling for monocultures could also limit women's income and ability to provide for household needs. More research on the question of the relationship between crop diversity and nutrition is desperately needed as large-scale agricultural interventions throughout sub-Saharan Africa are in a renewed phase of promoting staple crops among small farmer households.

CHAPTER 7

A CASE STUDY OF TRADITIONAL AFRICAN VEGETABLES ILLUSTRATING THE NUTRITIONAL IMPORTANCE OF VARIETAL DIVERSITY IN CROPS

7.1 Introduction

Explicit inclusion of nutrition is important in agricultural development projects to improve the chance of the projects having positive nutritional impact [197]. One approach to target nutrition through agriculture explicitly is to promote plants with higher bioavailable amounts of specific nutrients. This approach could improve nutrition among target populations, but nutrient content of varieties is only one aspect of how specific foods can affect nutrition. It is important for interventions promoting specific varieties for improved nutrition to be implemented within an awareness of the context of household behavior associated with consumption of promoted crops.

There are several dimensions to how the nutritional content of crops ultimately affect nutrition. One dimension is the nutrient and phytochemical density of the varieties consumed, as well as how bioavailable the nutrients are, and how stable they are during cooking and storage. Another dimension is how often the food is consumed, and how much of it is consumed, particularly among vulnerable groups. This involves not only palatability in general, but palatability to all members of the household specifically: nutritional gatekeepers (often women), influential decision-makers (often men or elders), and vulnerable groups (children). It also involves agronomic characteristics (yield, pest resistance), and marketing potential, which influence the amount that may be grown. A third dimension is the magnitude of other possible health attributes of a variety, such as medicinal potency, which can affect nutrition both through limiting disease and encouraging consumption (see Chapter 4); or through its unique role in recipes that are otherwise very nutritious and that would not be prepared without the specific variety required. (For example, Tuscan white bean soup cannot be made with black or pinto beans, and pozole cannot be made with yellow maize; both are rich food mixtures that are prepared dependent upon the presence of a certain variety of the key ingredient.) All of these dimensions determine how much nutrition can be obtained from a crop for the people who grow and consume it. It is important to understand how varieties are used in the household, to be able to understand how promoting new varieties might affect nutrition.

An understudied aspect of crop promotion for nutrition is the use of varietal diversity to achieve nutritional goals, as opposed to single-variety solutions. In the agricultural literature, some researchers have explored the agronomic effects of sowing multiple varieties [78, 304, 252]. In the nutrition literature, the research to date that tests the nutritional impact of varieties focuses on specific varieties that are either high-yielding (for enhanced food security and income generation) or high in specific amino acids or micronutrients (for improved protein intake or micronutrient status) [303, 86, 92, 193, 107, 26]. Some researchers have pointed to the possible benefits of varietal diversity based on nutrient variation [257, 81]. No empirical research in the nutrition literature has explored the possible nutrition effects of varietal diversity as compared to single varieties.

The objective of this study is to explore social, behavioral and biochemical evidence for whether the production and consumption of more than one variety of the same crop may have a positive effect on nutrition over and above the use of a single variety.

7.1.1 Research questions and hypotheses

Research questions:

1. How diverse are traditional African vegetable (TAV) production systems in Kiambu and Arusha; how many varieties do farmers typically grow, collect, and consume? Why would people choose to grow or consume more than one variety of any given vegetable crop?

2. Is diversity within a specific food crop associated with greater consumption of that crop, by households and vulnerable groups within households?

3. Is diversity of one crop related to consumption of other foods it is commonly cooked with?

4. Can a single best variety necessarily be identified in terms of nutrient density?

5. Is diversity within a specific crop associated with any other health consequence apart from nutrient intake?

Hypotheses:

1. (No hypothesis for research question 1 - descriptive.)

2. If more varieties are grown or consumed, consumption frequency and amount will increase. This hypothesis is founded on evidence that people eat more when a greater variety is presented to them - either of different foods (buffet effect) or of different varieties of the same food (e.g. different yogurt flavors[218], increased number of colors of M&M candies [126]). Without variety, consumption is lower due to sensory-specific satiety [217], which may last more than one eating episode.

3. Consumption of other foods usually cooked with TAVs will increase if more TAV varieties are consumed

4. No single variety will be able to be classified as the all-around "best" nutritionally, because nutrients will not co-vary unilaterally across varieties.

5. Diversity in crops, vegetables or herbs in particular, may be related to their medicinal use; different varieties may have different medicinal uses or strengths, which has been observed to be related to consumption as a food.[Ch. 4][188, 117, 65, 185]

7.2 Methods

7.2.1 Study sites and research setting

The research was conducted in Kiambu, Kenya, a district in Central Kenya that borders Nairobi, and Arusha, Tanzania, which surrounds Arusha town in northern Tanzania. The main tribal groups living in each site were Kikuyu in Kiambu, and Wa Arusha (sometimes called "sedentary Maasai") in Arusha. Information to answer the research questions was gathered within the context of an evaluation of a program working with small farmers in both regions to produce and market traditional African vegetables (TAVs). Five TAVs were promoted in the program: amaranth *Amaranthus* spp. and nightshade *Solanum nigrum/scabrum/americanum*, sweet potato leaf *Ipomoea batatas*, cowpea leaf *Vigna unguiculata*, and spider flower plant *Cleome gynandra*. Qualitative and quantitative information was gathered about farmers' production, sales, preference, and consumption of varieties of these five crops. The main data collection instruments were focus group discussions and a household survey.

7.2.2 Focus group discussions

Focus group discussions (FGD) were held to understand TAV variety extent and use in each district surveyed. In Kiambu, 15 FGDs were held (5 women-only, 5 men-only, and 5 mixed gender), and in Arusha, 7 FGDs were held (2 women-only, 1 men-only, 4 mixed gender) before the survey was administered. The average number of participants in each group was 11. Participants were selected based on membership in a farmer group which was growing TAVs, and voluntary expression of interest to participate. The setting for each was usually in a central community meeting place such as a school, hall, or church, or sometimes in a community leader's home. Information discussed in the FGDs included for both amaranth and nightshade, how many varieties are grown, what are the main characteristics of each, which are generally preferred in the community, and which ones young children prefer. Some limited information was gathered on varieties of sweet potato leaf, cowpea leaf, and spiderplant. Each FGD lasted approximately 30-60 minutes, and other topics not related to the research questions of this paper were covered in the discussion. Discussions were simultaneously interpreted between English and Kikuyu/Kiswahili by collaborators who were fluent in both languages and had extensive previous experience conducting FGDs for research. Information discussed was recorded as notes.

Another round of FGDs were held after the survey, in order to share results from a previous survey. These FGDs also elicited some useful information pertaining to use of TAV varieties, although the topic of the FGD was not specifically about TAV varieties. Therefore observations from these FGDs are included in the qualitative results as well. The second round of FGDs included 6 discussions in Kiambu and 4 in Arusha (all mixed gender). Attendance, setting, and length of FGDs were similar to the first round.

7.2.3 Survey data collection and analysis

Survey data were collected in 2008 from 169 households in Kenya and 207 households in Tanzania. Approximately half of the sample was randomly selected from eight communities not participating in the program promoting production and marketing of TAVs (four communities in each country), and half were selected on the basis of participation in the program, from eight communities (four in each country) where the program was operating. The primary factor associated with participation in the program was growing TAVs. As a result of this sampling technique, households that grew TAVs were oversampled relative to the general population. The study thus had greater power to detect associations between TAV variety-growing and consumption, but must be interpreted with the caveat that results are sourced from a population of households with a greater than average propensity for growing TAVs, and greater than average motivation to join a group marketing program.

The survey was administered over a period of four to five weeks simultaneously in both sites, which ensured comparable seasonality. Teams of interviewers administered the questionnaire in the local language of respondents, which was Kikuyu in Kenya, and Kiswahili or occasionally Maasai in Tanzania. The survey took one to two hours to complete for each household, covering a range of topics related to agriculture and nutrition, including: household demographics, assets, income sources, agricultural production (focused on TAVs), diet, nutrition knowledge and attitudes about TAVs, medicinal knowledge and use of TAVs, and diet of children age 2-5.

There were one to two respondents for each household. The sections on TAV production and sale were administered to the person in the household mainly responsible for TAV production. The sections on diet, including TAV consumption, and use if TAVs for medicine were administered to the person mainly responsible for taking care of the reference child age 2-5 (or if there was no child, the person responsible for the majority of the cooking in the household). These respondents were sometimes but not always the same.

Measurement of TAV production

The questionnaire was used to gather information on whether the farming household produced each of the five target TAVs in the last season (six months). For any TAV the farmer produced, detailed information on amounts harvested sold was gathered through respondent recall. Respondents were also asked if they ever collected any of the vegetables from the wild. After gathering harvest and wild collection information for each TAV, respondents were presented with picture charts of 5-6 varieties of each TAV, and asked which of the varieties (including "other") they had planted or collected, sold, and then which they *preferred* for eating. The varieties pictured were chosen with the assistance of expert staff at AVRDC-The World Vegetable Center, Regional Center for Africa in Arusha, Tanzania, who identified the varieties most likely to be used in each site. There are many other varieties of each vegetable, which farmers could identify by choosing an "other" variety. The picture charts are shown below for amaranth and nightshade (Figures 7.1 and 7.2, and are also included in the questionnaire in Appendix A.

Measurement of TAV consumption

The survey questionnaire included a 7-day food frequency questionnaire (FFQ), validated by Helen Keller International (HKI) [219], with a list of 33 food items, including 5 different traditional African vegetables: amaranth, nightshade, African spiderplant, cowpea leaf, and sweet potato leaf. Other leafy vegetables commonly consumed included cabbage, kale, and chard (known locally as "spinach"). The full

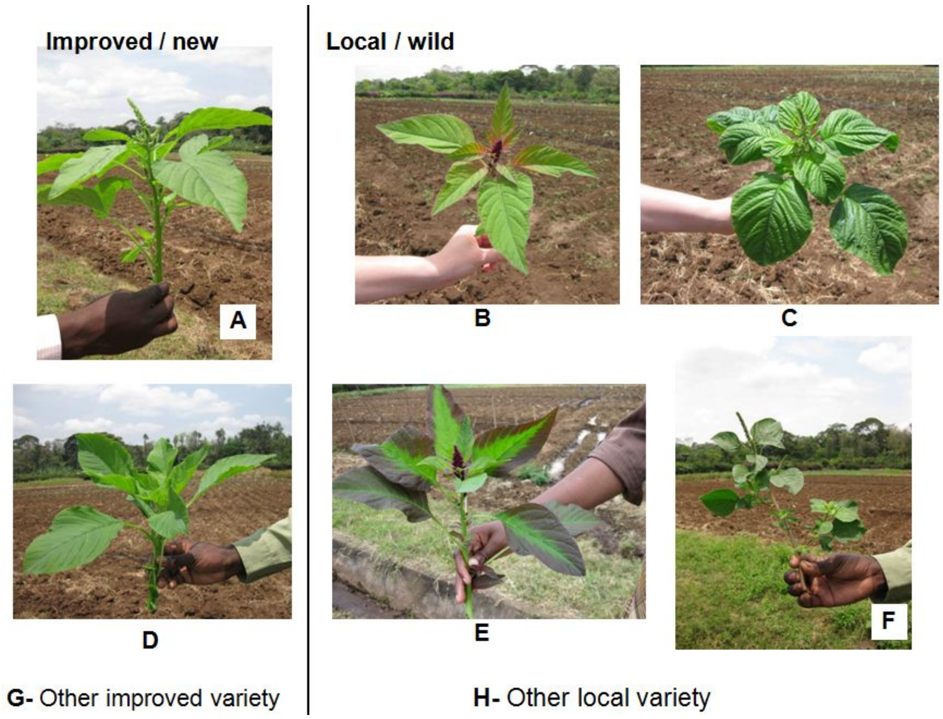


Figure 7.1: Pictures of six amaranth varieties in the survey questionnaire

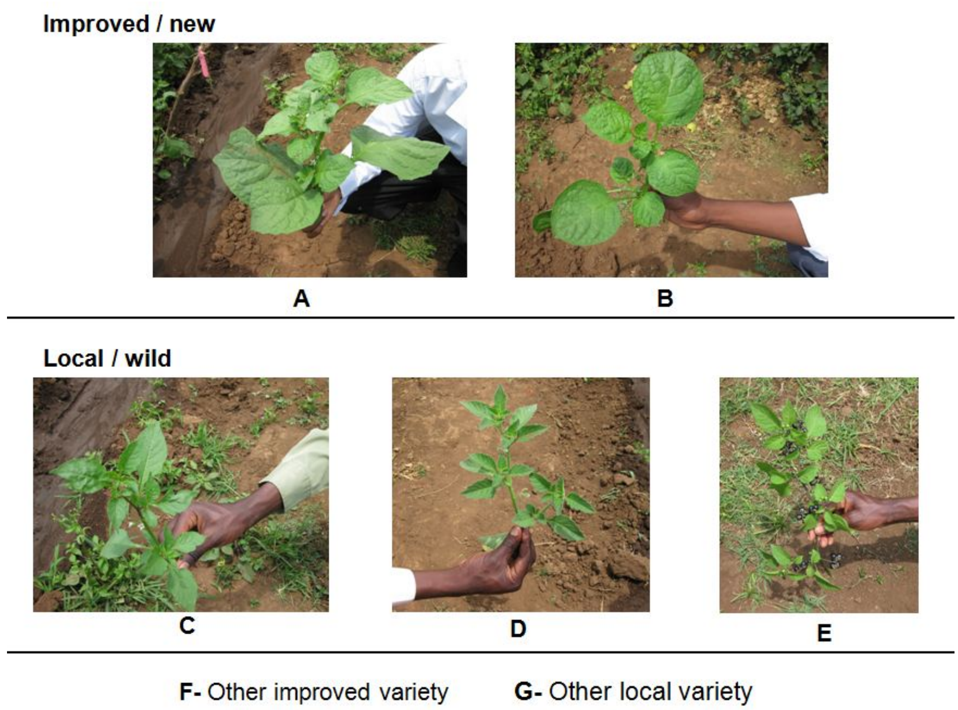


Figure 7.2: Pictures of five nightshade varieties in the survey questionnaire

FFQ is shown in Appendix A. Frequency of TAV consumption was counted as the maximum days any one TAV was consumed. Frequency of other leafy vegetable consumption was counted as the maximum days cabbage, kale, or spinach was consumed. If any TAV was consumed in the household, respondents with children age 2-5 were asked if the reference child consumed the vegetable as well. The amount consumed was estimated using a child-size standard bowl the enumerators carried to the household. The standard bowl was widely available and many respondents owned the same item in their household.

If respondents consumed any of the traditional vegetables, they were later shown the same picture charts of 5-6 common varieties of each vegetable, and asked to identify which of the varieties they consumed during the previous week.

Measurement of other constructs

Medicinal use of TAVs was measured by the pre-tested question, “Has consuming TAVs helped you or someone in your household with any particular illness personally?” If the answer was yes, the household was further asked which illnesses were treated with which TAVs. Attitude was measured as a scale of three questions assessing overall desire to consume TAVs, gender norms of TAV consumption, and willingness to serve TAVs to visitors. (See Chapter 3 for a detailed explanation of the attitude scale.) Wealth was measured as the sum of real market values of 23 durable goods and livestock that the respondent was asked if the household owned.

7.2.4 Data entry and analysis

Questionnaire data were double entered using CSPro data entry software (version 4.0) [42], onto electronic forms that looked identical to the printed survey questionnaire.

Focus group notes were reviewed and cleaned/clarified within 24 hours of the FGDs, and were then typed and coded. Notes were subsequently organized in a data spreadsheet (MS Excel) by code topic.

Statistical analysis

All analyses were run separately for each site, using PASW statistical software (version 18.0) [247]. Total number of varieties eachhousehold listed on the questionnaire were counted, and means and frequencies were used to determine the average number of varieties grown, sold, preferred and consumed, as well as the percent of the population that grew, sold, preferred, or consumed more than one variety per TAV.

Mixed effects models were used to analyze cross-sectional associations between the number of varieties grown or consumed with the frequency of TAV consumption at the household level and amount of TAVs the reference child consumed. Analyses based on number of varieties grown were limited to households who grew or collected any TAVs; likewise, analyses based on consumption were limited to households who consumed any TAVs. Variables of interest were entered as fixed effects, and district and village entered as random effects, to control for the complex sampling design of the survey. The same model type was used to analyze whether child consumption varied based on whether the variety consumed was wild, improved, or a mix of both. Generalized estimating equations logistic regression was used to analyze whether household medicinal use of TAVs (yes/no) was related to TAV variety.

7.2.5 Review of nutrient analysis

Nutrient analyses of several varieties of amaranth, nightshade, and cowpea leaf were carried out at AVRDC headquarters in Taiwan. All plants analyzed were grown under the same conditions and analyzed during the same time period using the same methods. The results of those nutrient analyses are interpreted here.

The detailed methods for nutrient analysis are provided here, as written in an unpublished AVRDC document:

"Nine accessions of African nightshade and four accessions of amaranth were used for nutritional evaluation. The seeds were obtained from Tanzania, Cameroon and Kenya. African nightshades were sown on 7 September, transplanted on 17 October and harvested on 9 November 2006, all in the experimental field of AVRDC-The World Vegetable Center, in the lowland of Southern part of Taiwan. Accessions of the two crops were replicated twice and arranged in a randomized complete-block design. The plot included 40 plants, 15 cm between plants within row and 15 cm between row on a 1 m wide bed.

Leaves were washed and dried by air flow for 1 hour. About 600g edible leaves of each sample were taken, cut into 2 x 2 cm small pieces, and mixed thoroughly. Half of the cut leaves were weighed in a net bag, 50C oven dried for 24 hours, and ground to fine powder for subsequent analyses of dry matter, protein, fiber, and minerals. Another half of the cut fresh leaves were weighed in several 20g plastic bags with seals and stored at -70°C for analyses of carotenoids, vitamin C and antioxidant activity.

The determination of calcium, iron and zinc contents were performed by ashing procedure, strong acid washing and then detection with Atomic Absorption Spectroscopy. The determination of total ascorbic acid was carried out on the basis of coupling 2,4-dinitrophenylhydrazine (DNPH) with the ketonic groups of dehydroascorbic acid through the oxidation of ascorbic acid by 2,6-dichlorophenolindophenol (DCPIP) to form a yellow-orange color in acidic conditions. For carotene analysis, the laboratory was kept dark during carotenoid operations and glassware were either of brown color or protected from light. Carotenoids in 20g frozen leaves were extracted with 80 mL acetone. Separation and identification of carotenoids was performed using a HPLC system (Waters Alliance 2695, Milford, MA). Commercial carotenoids (violaxanthin, neoxanthin, lutein, alpha-carotene, all trans-beta-carotene) were used for qualifications and quantifications after being measured for concentrations calculated according to their OD reading and specific extinction coefficient in their respective solvent. Antioxidant activity was measured using an ABTS radical , expressed as Trolox equivalent." (AVRDC, unpublished)

7.3 Results

7.3.1 Descriptive household use of TAV varieties

Focus group discussions with farmers generated information about why households plant or use more than one variety of each TAV. In all communities, more than one variety of both amaranth and nightshade were actively used. In most communities, respondents discussed two to four main varieties of each. Varieties were usually described as local or new, and in terms of leaf color and shape. Because descriptions were very generic ("small green leaves" vs. "broad leaves"), it is possible that respondents were categorizing several distinct varieties into a smaller number, either for the sake of the discussion or in their own conceptualization of use. FGDs revealed that the main reasons for growing several varieties involved agronomic traits, household and child taste preferences, and consumer preferences and marketability.

One important factor was agronomic traits, particularly speed of growth, delayed seeding, and large leaves which were easier to bundle than small leaves. One farmer noted, “I don’t prefer small leaf because it produces seed faster. I prefer broad-leaf because you can harvest it more times.” Another said, “In nightshade, all varieties have the same vigor. However you get more value from the big leaf varieties, because the leaves are broad and fewer are needed to make a large bundle.” This was echoed several times: “There are shallow leaves (local variety), which are preferred but difficult to manage; broad leaves (new variety), which are economically useful, and produce a higher volume.” Another farmer spoke specifically about growth speed: “The one [variety] which takes shorter - you can...harvest it first, before harvesting the other.” The farmer was indicating that there was an advantage to growing several varieties with staggered maturation rates, so that there could be a continuous flow of income and food provision.

Pest resistance also played a role in variety selection. One participant stated, “We were given [TAV] seeds from AVRDC/FCI but mainly cowpea - many varieties. We planted those seeds, but they are highly affected by pests compared to the indigenous ones.” Another noted, “I am not sure about the new varieties - but when we go to the wild there are no insects on the leaves. But the new varieties have pests. Which is better for health? Because we are concerned about consuming vegetables sprayed with pesticide.” It is often the case that local wild varieties may be better adapted to local pests than domesticated varieties.

Health reasons occasionally surfaced elsewhere in discussions for reasons to choose one variety over another. Respondents often talked about mixing different TAVs and varieties together: “[We eat] for health reasons; it is also tasty to mix together.” One woman stated her preference for wild varieties of nightshade, saying, “Because of being bitter, the old one (wild variety) helps cure stomach problems.” Another person concurred, saying that the local one cures worms because the bitter leaves are like medicine; so the mother usually prepares those. TAVs can be harvested multiple times per planting, and one woman referred to taste differences based on stage of harvest: “The new one is nutritionally good because the older one you have to boil for a long time and throw out the water and the nutrients.” Antinutritional factors in some varieties or later harvests may require more processing which affects their nutrient content when consumed.

Many respondents agreed that they would eat all varieties, but that the wild ones are preferred. However, wild varieties appeared to be preferred by *adults* while it was a different story for small children. The situation is summed up by the quote, “In general the local one [nightshade] is preferred but children prefer the taste of the improved big-leaf variety.” Another mother adopteed the child’s preference directly: “I don’t prefer the wild one. It is bitter, and kids don’t like it. I only make one pot for the whole family, so everyone has to like it.” There was general agreement that, “Small children will eat TAVs. But if you give them wild TAVs, it is too bitter for them.” Another respondent said, “We mix [the varieties], so the kids can’t distinguish the varieties. They are not used to nightshade alone.” In one interview this was observed firsthand: a woman prepared nightshade and served some to her 3-year-old granddaughter for a snack. The child took several bites - clearly being used to consuming leafy green vegetables - but then refused to eat more, saying that it was too bitter. The grandmother, slightly embarrassed, said that she had not mixed it with anything.

In one FGD of men, there was a heated debate in response to the question: “So if you like the local ones and kids like the improved ones, which one does mama make?” One opinion was that the mother ends up making the one the kids prefer. Another person offered that “Children prefer improved varieties - they take a lot and finish all of it." To this, another respondent agreed: "I have four kids. We cannot cook what my kids don't like. Therefore, my wife cooks the improved variety." However, two others dissented. One said, "My kids must eat what I like. My wife cooks the local variety," to which another respondent added, "When we make the local variety, the kids don't eat much of the vegetables, so I can eat more and also we don't have to prepare as much. But when my wife prepares the broad-leaf variety, the kids eat a lot, and I don't get as much, and we have to prepare more. So I prefer for her to prepare the local variety!" This exchange illustrates well the intra-household bargaining about food, where some households are more likely to capitulate to the child's taste and change their own eating habits, while others demand that their children eat like the rest of the family. Most households reported feeding TAVs to small children, but for some, the importance of ensuring that children receive adequate amounts of micronutrient-rich foods including vegetables may not have been well-understood.

The household preferences many farmers voiced were, not surprisingly, reflected in consumer preferences. In Arusha, a respondent said, "Customers prefer the local one (narrow leaves) because of experience - they are not familiar with the new, but that may change over time." In Nairobi, there was a similar thread: "Higher prices can be demanded from the wild one (green [amaranth]); second-highest is the big leaf variety, and third the new one." Another respondent: "The supermarket prefers the broad-leafed [improved] variety; locally, people prefer wild. People don't immediately switch tastes to the new varieties." Supermarkets determined the variety planted for other farmers in Kiambu: "Uchumi (major Nairobi supermarket) will not take the purple leaves; they complain that it's grown in sewage." That purple/reddish leaves in amaranth were caused by production with sewage water was a common myth in both Nairobi and Arusha among city-dwellers, which reduced farmers' motivation to plant red-leaf varieties. Another respondent said, "The wild varieties have high demand; people think others might be grown with sewage - especially the red ones." In Arusha, "Customers also like all [amaranth varieties] except for the red one - they will only buy it if there is a scarcity of the others." Different consumer outlets appeared to provide sources of demand for different varieties, except that the reddish varieties, used in other parts of Africa, were not often preferred by consumers in these sites.

These results are conclusive that several different varieties fulfill different, sometimes competing needs for households. Some varieties are faster to grow and sell, while others are more difficult to manage but command greater prices; many consumers prefer the strong wild varieties, but large commercial supermarkets prefer to buy and sell large-leaf, sweeter/blander varieties. Within households, adults generally seemed to prefer wild varieties although there was heterogeneity; a major reason for shifting to newer varieties is that they were better-accepted by children. Multifunctionality of varieties (for growing, selling, and eating) was of basic importance. Within communities, it was clear that no one variety would suffice to meet all requirements. In one FGD, a respondent said (like many others), "During this season, local nightshade gets too bitter. Kids prefer the sweeter ones...Kids eat amaranth and kales, not nightshade, although they may eat the improved varieties." Yet in the same group, someone said: "The improved ones are not yet favored by customers; most people don't yet know the taste." This points to the need for different varieties for different purposes: consumers prefer one (in this case, the traditional wild leaves), but households preferred another (in this case, the domesticated variety).

Quantitative descriptive results

Quantitative results agree with qualitative results, in showing that most households use more than one variety of each TAV. Varietal diversity for all categories was generally slightly higher in Tanzania than Kiambu, particularly for amaranth and nightshade. Of those who grew TAVs, about two-thirds in each site grew more than one variety of at least one TAV; of those who sold any, about one-third sold more than one variety; and of those who consumed any TAVs, about one-third consumed more than one variety within the week prior to the survey (7.1).

Table 7.1: Mean number of varieties grown (out of those who grew any), sold (out of those who sold any), preferred for eating (out of those who grew), and consumed (out of those who consumed any)

		Grow or collect mean (n)	Sell mean (n)	Prefer mean (n)	Consume mean (n)
Amaranth	K	1.84 (87)	1.48 (66)	1.36 (84)	1.30 (128)
	T	2.30 (102)	1.55 (44)	1.72 (103)	1.49 (112)
Nightshade	K	1.57 (87)	1.22 (69)	1.14 (79)	1.23 (98)
	T	1.89 (99)	1.24 (54)	1.40 (102)	1.27 (130)
Spiderplant	K	1.13 (47)	1.04 (27)	1.03 (37)	1.00 (32)
	T	1.50 (28)	1.20 (5)	1.11 (37)	1.00 (15)
Sweet potato leaf	K	3.00 (4)	n/a (0)	2.33 (3)	1.25 (4)
	T	1.28 (50)	1.00 (6)	1.16 (61)	1.04 (69)
Cowpea leaf	K	1.67 (9)	1.33 (6)	1.25 (8)	1.00 (3)
	T	1.07 (81)	1.66 (17)	1.11 (83)	1.00 (52)
% who used more than one variety of at least one TAV	K	62.2 (98)	32.1 (84)	29.6 (98)	33.1 (136)
	T	69.2 (146)	33.3 (78)	53.4 (146)	30.6 (180)

Note: K = Kenya, T = Tanzania

Figures 7.3 and 7.4 show for each site, the distribution of the number of varieties grown or collected in excess of the number of TAVs cultivated. The number of varieties shown on the x-axis is equal to the total number of varieties grown or collected minus the number of TAVs (amaranth, nightshade, spiderplant, cowpea leaf, sweet potato leaf) grown or collected. A zero value signifies that the farmer grew exactly one variety of each type of vegetable she or he grew. (i.e. Even if the farmer grew all five TAVs, if he/she grew only one variety of each, the number of excess varieties grown = 0. If the farmer only grew amaranth, but grew 8 varieties of amaranth, the number of excess varieties = 7.)

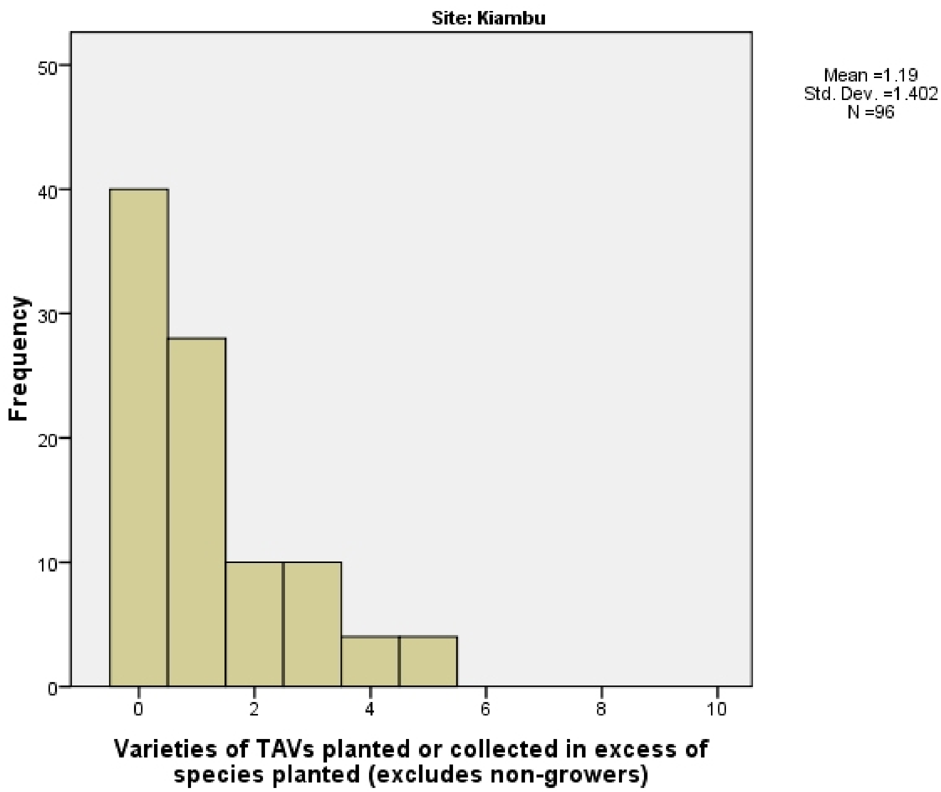


Figure 7.3: Distribution of the number of varieties grown in Kiambu

Figure 7.5 shows the correlation between number of varieties planted and varieties collected from the wild. In Kiambu, growing TAVs appears to substitute for collecting them; many fewer farmers who grow TAVs collect them from the wild than farmers who do not grow TAVs. In Arusha, however, there is no relationship between growing and collecting; the households who grow TAVs are just as likely to collect them also. The Spearman correlation between growing and collecting

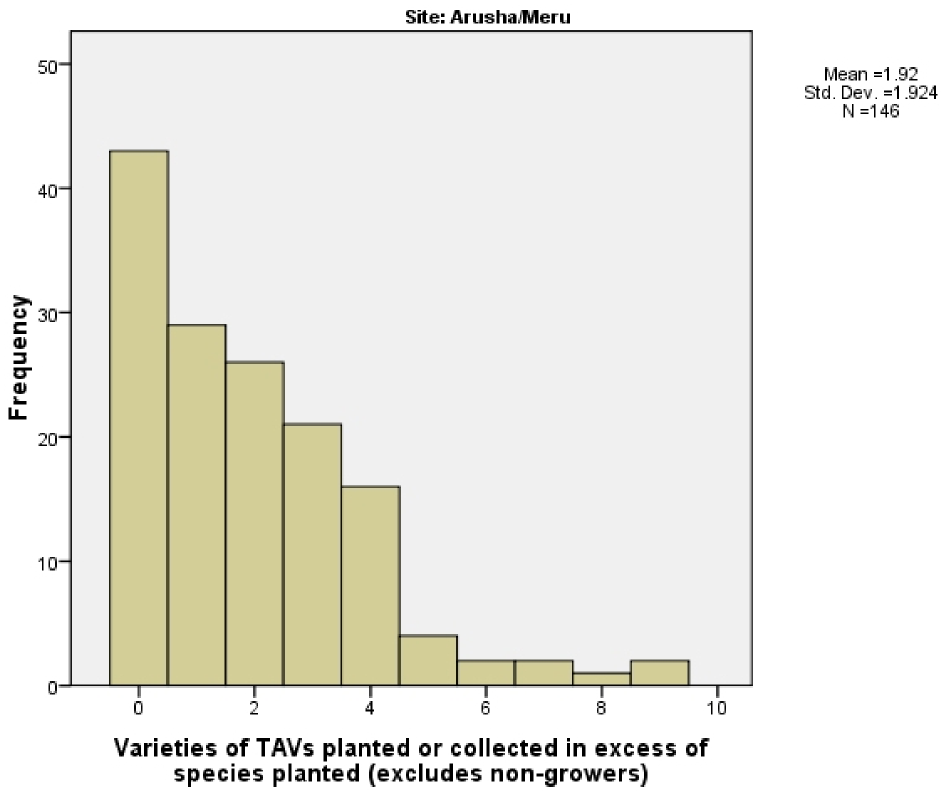


Figure 7.4: Distribution of the number of varieties grown in Arusha

TAVs is -0.316 ($p<0.001$) in Kiambu, and is 0.046 (NS) in Arusha. These statistics do not measure amount collected; it is possible that Arusha households who grow TAVs collect fewer from the wild than non-growers. What the data may more accurately illustrate is that even if some varieties are cultivated in Arusha, they do not substitute for some varieties which grow wild, either for food or medicinal purposes. That is, in Arusha, unique varieties are uniquely valued. An alternate interpretation is seasonality; more Kiambu households who grow TAVs may have them available year-round, while more Arusha households may grow TAVs seasonally and collect wild TAVs only when they are not growing them. The explanation does not appear to bear out, though, because as seen in Chapter 2, while Arusha households are more likely than Kiambu households to grow seasonally, they are fairly similar, with around 50% of households growing year-round in both countries. Farmer demand for several unique varieties in Arusha is a more likely explanation.

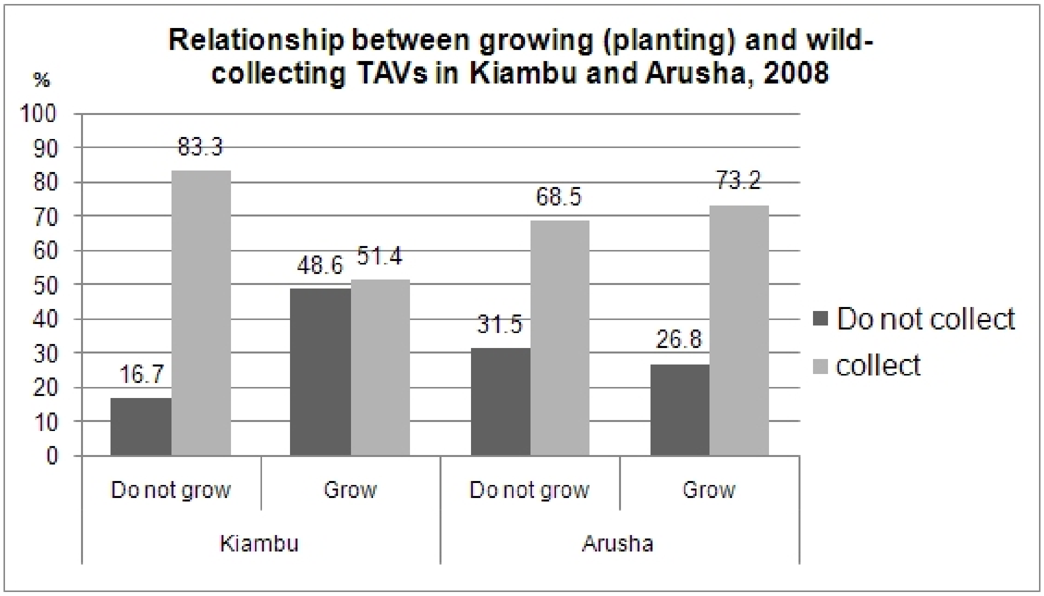


Figure 7.5: Relationship between cultivating and wild-collecting TAVs

This paper will focus on amaranth and nightshade, because those are the two types of vegetables with the largest discernable variation, among the five vegetables targeted. Both cowpea leaf and African spider plant have many varieties, but they are not easy to discern visually, and so it was not possible to collect data on specific varieties using the survey questionnaire. Sweet potato leaf varieties are easily discernable, but it was not a crop grown or consumed by many farmers compared to the other vegetables, so limited data were available to analyze correlations with consumption. Amaranth and nightshade, however, have many distinct varieties and are very commonly grown and consumed, so they were ideal vegetable crops to study the link between diversity, consumption, and nutritive value.

Bar charts of amaranth and nightshade varieties grown, collected, sold, and preferred (Figures 7.6 through 7.9) show that there is no clear “most preferred” variety, particularly among amaranth varieties. (Variety labels correspond to the picture charts in Figures 7.1 and 7.2.) Some are preferred for growing and selling; these are not always the same that are preferred for eating. in Kiambu, nightshade variety "B" appears to be preferred overall while in Arusha variety "C" is the most popular, but in neither country is there a consensus; there were also a number of respondents who preferred other varieties. As discussed in the FGDs, the varieties farmers choose to plant are affected by how easy it is to grow, sell, and how much they like it, and perhaps, whether they can easily collect it elsewhere.

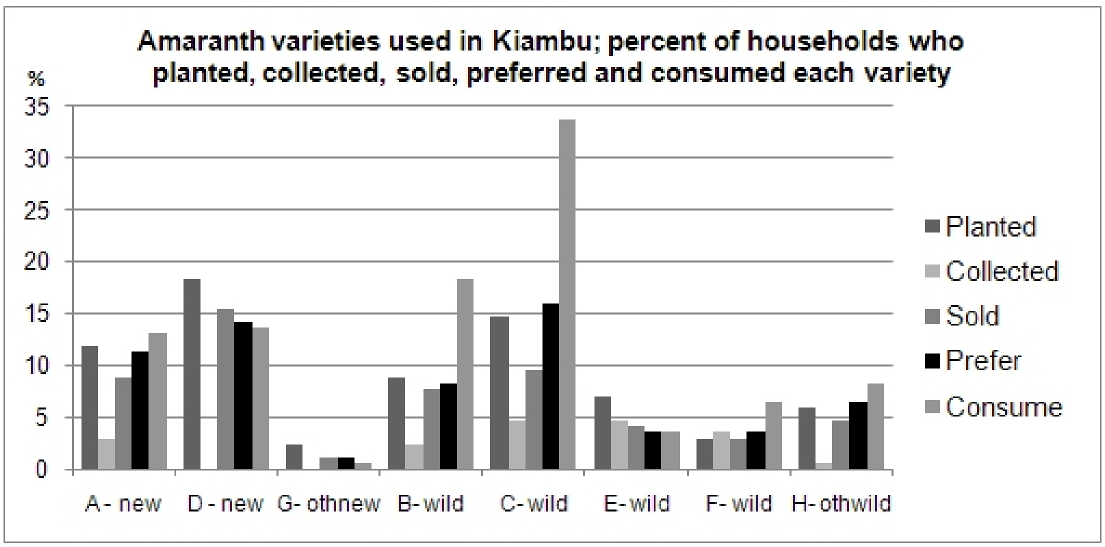


Figure 7.6: Amaranth varieties used in Kiambu

7.3.2 TAV diversity and vegetable consumption

Relationship between TAV diversity and household and child TAV consumption

Cross-sectional data from both Kiambu, Kenya and Arusha, Tanzania were used to test the hypothesis that TAV consumption increases if more varieties were consumed or grown. Results show that in Arusha, the number of extra TAV varieties consumed beyond the number of species consumed was significantly associated

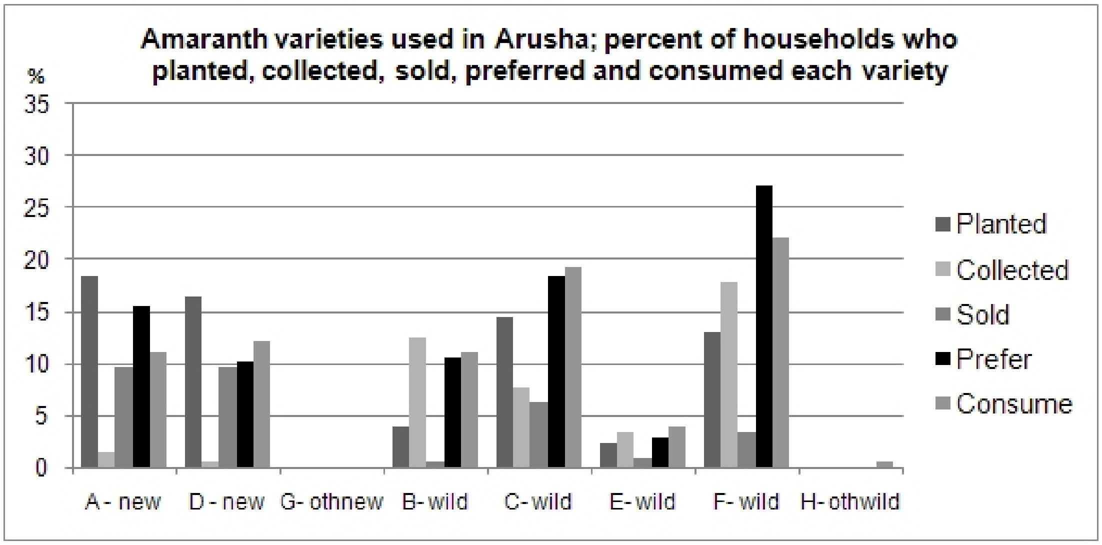


Figure 7.7: Amaranth varieties used in Arusha

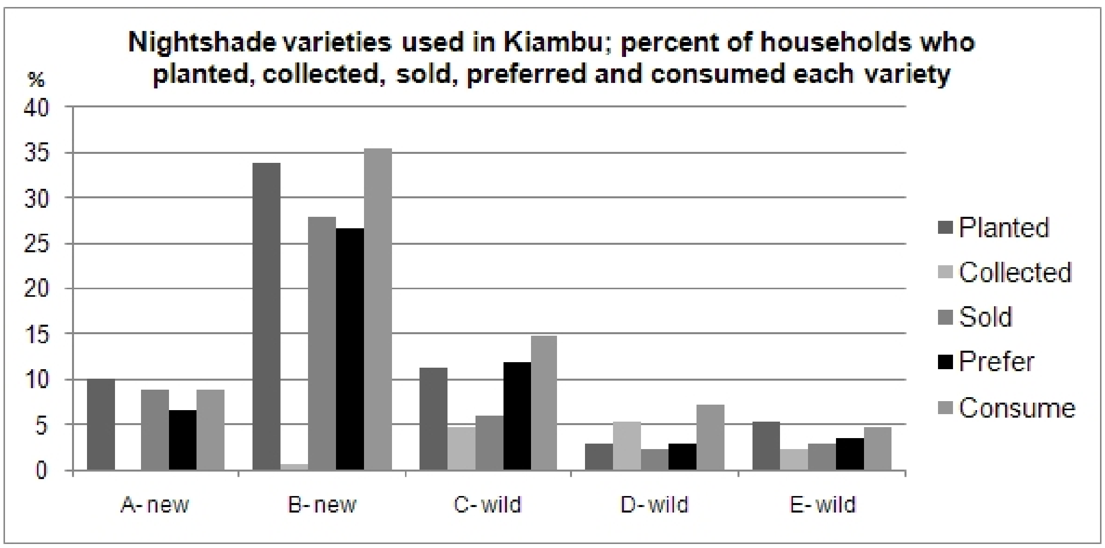


Figure 7.8: Nightshade varieties used in Kiambu

with both the frequency of TAV consumption at household level (0.4 days per week more frequently consumed for each additional variety consumed, p=0.03) and the amount preschool-age children consumed (16 g more per day, on average, p=0.001). Likewise, the number of varieties *grown* (in excess of the number of TAVs grown) was significantly associated with frequency of consumption (0.2 more days per week consumed for each additional variety grown, p=0.015), and

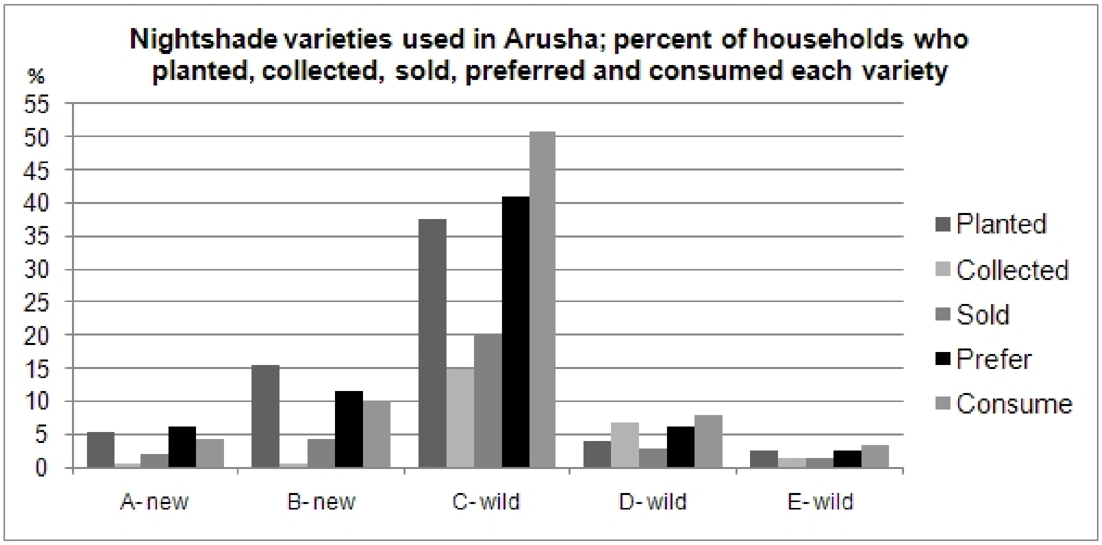


Figure 7.9: Nightshade varieties used in Arusha

child consumption (on average 8g more TAVs consumed for each additional variety grown, p=0.003). These results were robust when controlling for the amount of TAVs harvested over the season, which is important because it means that the reason more TAVs were consumed when more varieties were planted was not because a higher quantity was harvested. In Kiambu, the variables of interest did not approach significance (results table not shown).

In a subsidiary analysis, where a bivariate rather than continuous variable was tested, if the mean number of varieties consumed per species was greater than 1, on average TAVs were consumed 1.2 days more than if only one variety was consumed of each species consumed ($p<0.001$); children consumed 38 grams more, on average, if more than one variety was consumed ($p<0.001$).

Tables 7.4 and 7.5 show similar results for a specific TAV crop, rather than all TAVs combined. As the number of amaranth varieties consumed increased, Arusha households consumed amaranth on average 0.7 days more per week for each additional variety consumed (p=0.007), and children consumed on average 13g more per day of amaranth for each additional variety they were served (p=0.007).

Table 7.2: Arusha: The relationship between extra TAV varieties consumed (above the number of TAV species consumed), and household and child TAV consumption

	Household consumption (days/week any TAV consumed)		Preschool child consumption (grams/day of TAVs consumed)	
	n=170		n=135	
	Est. [S.E.]	p-value	Est. [S.E.]	p-value
No. of extra TAV varieties consumed	0.359 [0.164]	0.030	15.945 [4.704]	0.001
Wealth (ln value of assets owned)	-0.052 [0.097]	0.593	-0.220 [2.862]	0.939
Age of household head (years)	0.005 [0.012]	0.688	0.251 [0.354]	0.479
TAV production (total # varieties)	0.138 [0.053]	0.010	3.819 [1.500]	0.012
Attitude score	0.187 [0.134]	0.174	4.532 [3.645]	0.216
Program participation	0.188 [0.413]	0.673	6.021 [8.624]	0.486
Child age in months	-	-	0.306 [0.287]	0.289
Days child was sick in the previous 2 weeks	-	-	-1.038 [0.892]	0.246

Models controlled for district and village as random effects. The sample was limited to those who ate any TAVs.

Among amaranth growers, each additional amaranth variety sown or collected was associated with a 0.7-day per week increase in frequency of household amaranth consumption (p=0.005). There was no significant association between amaranth varieties grown and amount children consumed.

The same models shown for amaranth were also tested for nightshade. Neither number of nightshade varieties consumed nor grown was a significant predictor of nightshade consumption in either country. The lack of association was not due to smaller sample size, because the number of farmers growing or consuming nightshade and amaranth was similar. It may, however, have been due to the

Table 7.3: Arusha: The relationship between extra TAV varieties planted or collected (above the number of TAV species grown), and household and child TAV consumption

	Household consumption (days/week any TAV consumed)		Child consumption (grams/day of TAVs consumed)	
	n=110		n=84	
	Est. [S.E.]	p-value	Est. [S.E.]	p-value
No. of extra TAV varieties grown	0.242 [0.098]	0.015	8.108 [2.641]	0.003
Wealth (ln value of assets owned)	0.005 [0.144]	0.970	1.463 [3.839]	0.904
Age of household head (years)	-0.003 [0.153]	0.833	0.056 [0.433]	0.898
Attitude score	0.764 [0.276]	0.007	11.107 [6.196]	0.077
TAV Harvest amount (ln kg/season)	0.136 [0.109]	0.217	5.829	0.045
Program participation	0.686 [0.596]	0.318	7.097 [10.627]	0.522
Child age in months	-	-	0.456 [0.364]	0.215
Days child was sick in the previous 2 weeks	-	-	0.541 [1.133]	0.634

Models controlled for district and village as random effects. The sample was limited to those who grew any TAVs.

fact that the nightshade pictures in the survey did not pick up as much variation as the amaranth pictures; there were six amaranth varieties shown and only five nightshade varieties. The nightshade analyses tended toward the same direction and magnitude of association, but did not reach statistical significance.

Table 7.4: Arusha: Among amaranth consumers, the relationship between number of varieties consumed and household and child amaranth consumption

	Household consumption (days/week amaranth consumed)		Child consumption (grams/day of amaranth consumed)	
	n=109		n=83	
	Est. [S.E.]	p-value	Est. [S.E.]	p-value
No. of amaranth varieties consumed	0.703 [0.255]	0.007	12.641 [4.530]	0.007
No. of amaranth varieties grown or collected	0.434 [0.133]	0.001	2.750 [2.217]	0.220
Wealth (ln value of assets owned)	0.037 [0.154]	0.808	-1.382 [2.909]	0.636
Age of household head (years)	-0.005 [0.016]	0.761	0.176 [0.278]	0.529
Program participation	-0.179 [0.376]	0.635	1.653 [5.962]	0.782
Child age in months	-	-	0.182 [0.218]	0.406
Days child was sick in the previous 2 weeks	-	-	-1.235 [0.622]	0.051

Models controlled for district and village as random effects. The sample was limited to those who ate any amaranth.

Relationship between wild/domesticated varieties and child consumption

Because people frequently talked about varieties children liked as a powerful motivator for consumption of certain varieties, the relationship between specific variety and child TAV consumption was tested. There was not enough power to test each of the individual varieties asked about in the questionnaire, so for amaranth and nightshade, the varieties were divided into two categories: improved/domesticated and wild-type. This broad classification of variety type is justified because the hallmark of improved/domesticated varieties is larger, softer, and sweeter leaves

Table 7.5: Arusha: Among amaranth growers, the relationship between amaranth varieties planted or collected and household and child amaranth consumption

	Household consumption (days/week any TAV consumed)		Child consumption (grams/day of TAVs consumed)	
	n=74		n=74	
	Est. [S.E.]	p-value	Est. [S.E.]	p-value
No. of amaranth varieties grown or collected	0.718 [0.246]	0.005	NS	
Wealth (ln value of assets owned)	0.041 [0.179]	0.817	NS	
Age of household head (years)	-0.032 [0.023]	0.162	NS	
Amaranth harvest amount (kg/season)	0.0001 [0.00004]	0.016	NS	
Program participation	0.359 [0.584]	0.540	NS	
Child age in months	-	-	NS	
Days child was sick in the previous 2 weeks	-	-	NS	

Models controlled for district and village as random effects. The sample was limited to those who grew amaranth. "NS" = not significant.

than wild varieties. Those characteristics would seem to be relevant to children's willingness to eat them, since children are less tolerant of bitter flavors than adults.

The amount of amaranth children consumed was modeled as a function of whether the varieties consumed were improved, domesticated, or mixed, controlling for wealth, household head age, whether amaranth was produced, child age, and days the child was sick in the two weeks prior to the survey. The same structure model was carried out for nightshade as well.

In Kiambu, children ate 14g/day more amaranth, on average, if the amaranth variety was improved/domesticated rather than wild (n=58, p=0.027) (full results table not shown). There was no significant difference between those who ate a

Table 7.6: Kiambu: Among amaranth growers, the relationship between extra TAV varieties planted or collected (above the number of TAV species grown), and household and child TAV consumption, controlling for harvest amount.

	Household consumption (days/week any TAV consumed)		Child consumption (grams/day of TAVs consumed)	
	n=128		n=36	
	Est. [S.E.]	p-value	Est. [S.E.]	p-value
No. of amaranth varieties grown/collected	NS		8.335 [3.724]	0.034
Wealth (ln value of assets owned)	NS		-7.104 [3.575]	0.057
Age of household head (years)	NS		-0.081 [0.292]	0.784
Amaranth harvest amount (kg/season)	NS		-	-
Program participation	NS		16.935 [6.142]	0.010
Child age in months	-	-	-0.353 [0.254]	0.175
Days child was sick in the previous 2 weeks	-	-	0.253 [1.426]	0.861

Models controlled for district and village as random effects. The sample was limited to those who grew amaranth. Note: harvest amount of amaranth could not be included in the model for child amaranth consumption because it reduced the sample size by 20%, to n=28. It was not a significant predictor of child amaranth consumption. "NS" = not significant.

mix of improved and wild amaranth varieties vs. improved alone. (That comparison, though, was limited because only three children consumed both wild and improved varieties in Kiambu.) For nightshade those who consumed both wild and improved ate 16g/day more nightshade than those who ate improved varieties alone (n=48, p=0.023). Those who ate only improved varieties did not eat significantly more than those who consumed wild varieties only, though the sample size was again quite limited. The latter result could indicate that when more varieties were available for consumption (mixing wild and improved implies having at least two varieties), it encourages consumption. One reason may be that when wild and improved varieties are mixed together in the same dish, they are more palatable than either one alone, as discussed in the FGDs.

There was no difference in Arusha in amount of amaranth (n=71) or nightshade (n=100) consumed based on whether the variety was improved, wild, or a mix. Most mothers in Arusha mixed different varieties and species together, and in FGDs discussed this as an important strategy for getting their child to consume TAVs. These results may reflect that mothers in Arusha may deal particularly well with mixing varieties to cover the bitterness.

7.3.3 Relationship between TAV diversity and consumption of other vegetables

Because TAVs are often mixed with other vegetables, and farmers frequently reported greater palatability of vegetable mixtures compared to single-vegetable preparations, the data were analyzed to test if farmers ate more other green leafy vegetables (cabbage, spinach or kale) if they consumed a greater variety of TAVs. It was hypothesized that a greater variety of TAVs may provide more impetus for cooking other mixed leafy vegetables more often (that the vegetables are complements), although alternatively, TAVs could function as substitutes to other vegetables.

As seen in Table 7.7, there is evidence that the vegetables may be complements rather than substitutes. In Arusha, as the total number of TAV varieties consumed increased, the frequency of consumption of other leafy vegetables also increased (p=0.002). In Kiambu, a similar relationship and magnitude of association was seen, but it did not reach statistical significance (p=0.080).

Table 7.7: Consumption of cabbage, kale, and spinach dependent on the number of TAV varieties grown

	Dependent variable: Household consumption (days/week other leafy vegetables consumed)			
	Kiambu		Arusha	
	n=167		n=204	
	Est. [S.E.]	p-value	Est. [S.E.]	p-value
Total no. of TAV varieties grown or collected	0.191 [0.108]	0.080	0.218 [0.705]	0.002
Wealth (ln value of assets owned)	-0.277 [0.136]	0.044	-0.155 [0.081]	0.056
Age of household head (years)	0.027 [0.011]	0.014	0.002 [0.103]	0.852
Program participation	0.220 [0.325]	0.500	-0.146 [0.239]	0.580

When the analysis was re-run controlling for TAV harvest amount, the sample is halved because it is limited to those households who harvested TAVs. The relationships do not change, however; both the effect sizes and significance of the total number of varieties grown were approximately the same in both sites.

7.3.4 Nutrient content variation across varieties

This section addresses the question of whether nutrient content varies significantly and unilaterally across varieties. That is, is one single variety "best" micronutrient-wise, ignoring yield, palatability, and income-generating potential? Nutrient data from AVRDC headquarters in Taiwan are shown in Tables 7.8 and 7.9. These nutrient levels were compared by converting each level into a percent of the highest observed level for that particular vegetable, and graphed in figures 7.10 and 7.11. Of the varieties tested, the one with the highest content for each nutrient is identifiable where the nutrient level equals 100%.

Table 7.8: Nutrient composition (per 100g fresh weight) of four varieties of vegetable amaranth leaves

	Line	Fe (mg)	Zn (mg)	Vitamin A (μg RAE)	Vitamin C (mg)	Folate (μg)	Ca (mg)	α-tocopherol (mg)	Violaxanthin (mg)	Neoxanthin (mg)	Lutein (mg)	Total phenolics (mg)	Antioxidant activity (μmol TE)	Oxalic acid (mg)
Amaranthus cruentus	RCA-14	3.79	0.66	165.83	36	52	305	1.13	2.52	1.5	4.93	107	414	408
Amaranthus dubius	RCA-15	3.35	1.48	279.58	78	82	582	2.12	2.63	1.57	4.86	78	580	479
Amaranthus retroflexus	RCA-25	3.14	1.05	305.83	63	67	630	1.46	2.14	1.52	5.17	95	504	507
Celosia argentea	RCA-41	2.53	0.90	45.92	29	147	225	1.18	4.10	2.87	7.76	225	815	358

Source: AVRDC, unpublished data

Table 7.9: Nutrient composition (per 100g fresh weight) of nine varieties of nightshade leaves

	Line	Fe (mg)	Zn (mg)	Vitamin A (μg RAE)	Vitamin C (mg)	Ca (mg)	Violaxanthin (mg)	Neoxanthin (mg)	Lutein (mg)
Solanum sp.	IP05	3.02	0.61	194.17	72.5	226.5	2.08	1.27	3.19
Solanum sp.	IP15	2.59	0.48	273.75	92.0	217.5	2.44	1.19	2.88
Solanum sp.	MW09	2.44	0.49	162.08	55.5	178.0	2.44	1.34	3.19
Solanum scabrum	SS52d	1.61	0.55	152.92	85.5	176.0	2.28	1.03	2.39
Solanum scabrum	SS04.2b	2.18	0.65	151.67	100.5	220.0	1.66	0.88	2.26
Solanum sp.	ST30	2.87	0.49	145.21	54.0	193.5	2.12	1.07	2.41
Solanum sp.	ST10	2.74	0.59	139.17	99.0	209.0	1.49	0.89	2.29
Solanum sp.	ST26a	2.99	0.52	127.92	54.0	226.0	1.57	0.96	2.29
Solanum sp.	MW05	1.69	0.42	112.08	86.0	187.0	1.99	0.94	1.88

Source: AVRDC, unpublished data

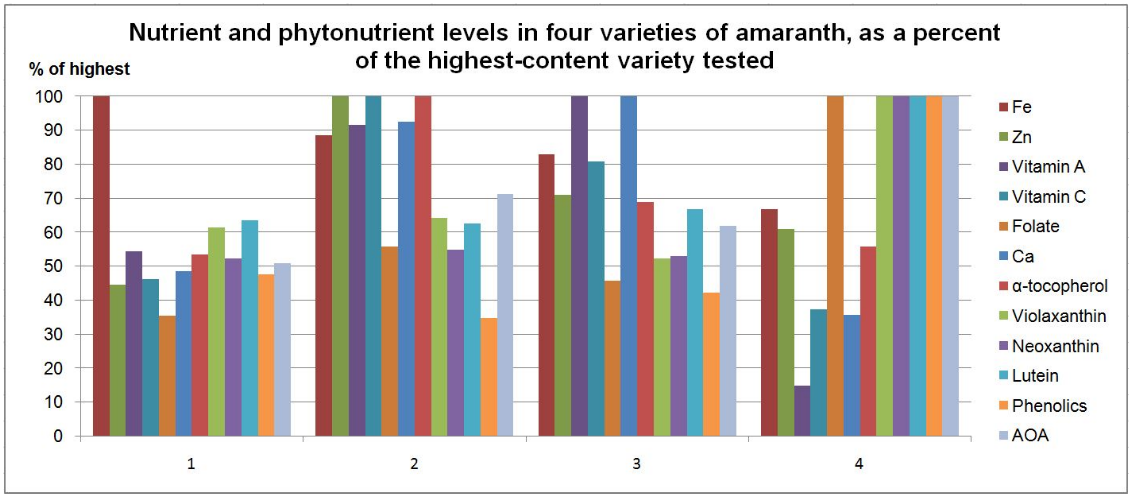


Figure 7.10: Nutrient and phytonutrient levels in four varieties of amaranth, as a percent of the highest-content variety tested

The results in tables 7.10 and 7.11 show that nutrients do not vary unilaterally across varieties; in varieties where one important nutrient is higher, other nutrients are lower. Among the four amaranth varieties tested, variety 1 is the highest in iron - probably higher than varieties 2 and 3 than it appears, since it is also relatively low in oxalic acid (see table 7.8), which inhibits iron absorption. However, it is also very low in vitamin C (an iron absorption enhancer) compared to varieties 2 and 3, and it contains only about 50% of the maximum of all the other nutrients. Variety 2 is highest in zinc, vitamin C and alpha-tocopherol, as well as having relatively high iron, vitamin A, and calcium, but is low on antioxidant carotenoids. Variety 3 is highest in vitamin A and calcium. Variety 4 is lower in vitamin A, vitamin C, and the minerals, but highest in folate and carotenoids which generally protect against oxidative stress; likewise, it is highest in phenolic content and total antioxidant activity.

Not all the same nutrients were tested in the nightshade nutrient analysis, but more varieties were tested. Nightshade varieties 1, 6, 7 and 8 are all in the high range for iron; 1 and 5 are the highest in zinc. Variety 2 is well above the rest in

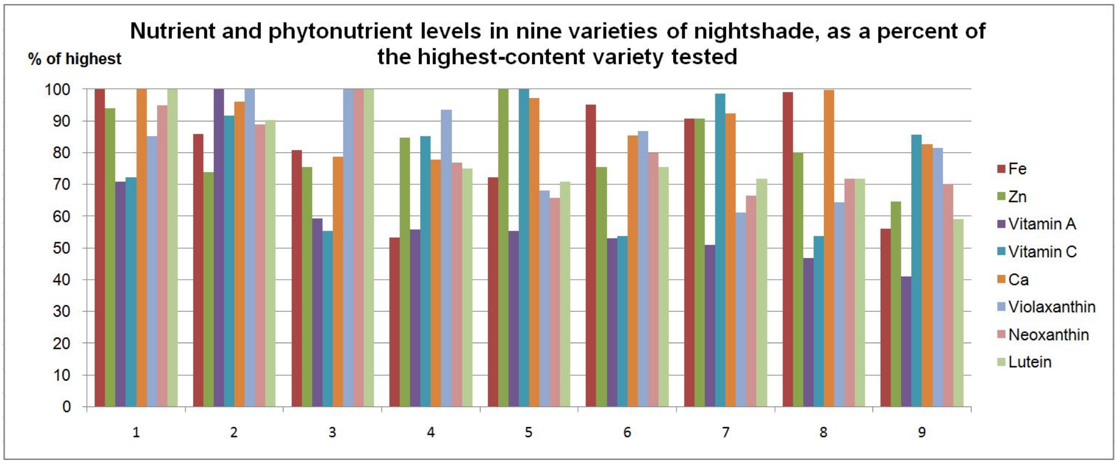


Figure 7.11: Nutrient and phytonutrient levels in nine varieties of nightshade, as a percent of the highest-content variety tested

vitamin A content. Varieties 5 and 7 seem to be highest in vitamin C, which might make variety 7 particularly high in bioavailable iron; however, along with varieties 1, 2, 5, and 8, it is also high in calcium which inhibits iron and zinc absorption. Variety 3 is has the highest antioxidant carotenoids levels, and varieties 1 and 2 are also high in the carotenoids. Notably, varieties 4 and 5 in the nutrient analysis are the same as varieties as nightshade varieties A and B in figures 7.8 and 7.9 above; variety 5 is particularly popular in Kiambu.

7.3.5 TAV diversity and non-nutrient health-related components

As described in Chapter 4, nutrients are not the only health-related motivation people have for consuming traditional African vegetables. Consumption is also related to medicinal uses, some of which are explained by nutrient content (e.g. treatment of anemia), and others which may be better explained by phytochemical bioactivity, such as treatment of stomach aches, rashes, or intestinal worms. Even if these medicinal uses do not have to do with nutrient content, anti-bacterial or anti-helminthic properties of vegetables, if they are real, do have to do with nutrition. A child who has fewer worms or whose stomach does not hurt can consume and absorb more nutrients. If the plants are effective medicinally, they can affect nutritional status through both the nutrient and health pathways [268].

This section examines the question of whether TAV diversity may have to do with medicinal use. Women in focus group discussions reported using wild varieties in particular to treat illness, because of their "bitter" properties. It is often the case that medicinal treatments are highly specialized and require unique varieties of a plant. Varietal diversity may be an important component of medicinal use.

To test the hypothesis that people are more likely to use TAVs medicinally if they consume or grow more varieties, a generalized estimating equation linear regression modeled the odds of households having used TAVs to treat a specific illness as a function of the number of varieties grown or collected in excess of species produced or collected. The model controlled for wealth, age of household head, caregiver's education, program participation group, and district as fixed effects. Village was entered as a repeated (random) effect.

In Arusha, each additional variety grown, beyond the number of species grown, was correlated with a 25% increased likelihood of using TAVs medicinally (n=167, $p<0.001$). In Kiambu, number of varieties was not correlated with medicinal use (n=202). This may reflect less specific medicinal knowledge in Kiambu than Arusha; as discussed in Chapter 4, medicinal knowledge about these specific TAVs appeared to be more recent in Kiambu and respondents were more likely to generalize medicinal properties across these TAVs. The only other significant predictor in the model was that in both countries, program participants were significantly more likely to use TAVs medicinally than non-participants: 36% more likely in Kiambu ($p=0.025$), and 45% more likely in Arusha ($p=0.001$). The association between varietal diversity and medicinal use was the same for program participants and non-participants (no effect modification).

7.4 Discussion

This paper is novel because to my knowledge, no one has ever published any analysis relating diversity within a crop to consumption behavior and possible nutrition effects.

7.4.1 Interpretation of the results

The descriptive statistics in this study are novel and important. Very little nutrition research presents data on varietal diversity in production, sale, consumption, and preferences. These data illustrate the complexity of cropping systems and household uses and needs for specific varietal characteristics. Beyond presenting quantitative data on diversity in traditional vegetable use, this study employs qualitative information to explain why people prefer wild or improved/domesticated varieties, and why they usually prefer to grow and/or wild-collect more than one variety.

This study also illustrates differences between two sites where TAVs are used. In Kiambu, there is a negative correlation between growing and collecting TAVs, but in Arusha, there is no correlation between growing and collecting TAVs. There are fewer wild areas in general from which TAVs could be collected in Kiambu, as land is more scarce; but also, fewer households in Kiambu wild-collected foods overall than in Arusha, where there is more space for wild collection as well as the tradition of doing so. The Wa Arusha, or sedentary Maasai, depended on a nomadic lifestyle for centuries before settling as farmers, and wild food collection -

particularly herbs - is a part of the culture. Also, as the farmers reported in focus group discussions, some of the wild varieties are more highly preferred for taste over the new more domesticated varieties, and farmers continue to collect these wild varieties even if they sow new varieties.

In Arusha, households who consumed more *varieties* of TAVs, beyond the number of TAVs grown, consumed TAVs more often and their children consumed more of them. It is well-demonstrated in industrialized countries that diversity in available food encourages consumption [218, 126, 287, 213]; this "buffet effect" may work for vegetables on the farm as well as for jelly beans or buffet entrees. A variety of vegetables may be more palatable than a single one which would lead to sensory-specific satiety. According to qualitative and observational data, almost every household preferred to consume a variety of TAVs (and other vegetables) mixed together rather than one single type. Households that consumed more species and varieties of TAVs also ate more of other vegetables. Although sample sizes were smaller for testing the associations in individual vegetables, the same pattern was seen in amaranth: households that consumed more varieties of amaranth ate amaranth significantly more times during the week, and children ate more volume of amaranth. The same relationships were not seen in nightshade where, as discussed, assessment of varieties was more limited by the survey instrument.

It is important to note that the correlation between number of varieties consumed and frequency of consumption is robust and not biased by the survey technique. Respondents were asked how many times/week each TAV was consumed for each TAV in general before they were asked about varieties. If respondents had been asked about frequency of consumption of each variety individually, it would have led to a correlation between frequency reported and the number of varieties consumed.

Related to diversity in production, given the same level of harvest, households who grew or collected more varieties of TAVs ate them more often, their children ate more of them, and they were significantly more likely to have actually used them to treat an illness in Arusha. The consumption effects could be related to saliency and again, palatability - if there are more varieties available, the household may be reminded of them more often (by seeing several kinds in the field), and may feel like consuming them more often. Alternatively to a variety/appetite mechanism, insights from the FGDs suggest that if planting more varieties was associated with more continuous availability of TAVs, any one variety would be ready for harvest at any given time (such as the week before the survey). Continuous availability could also explain why people at more if they grew several varieties, although that hypothesis was not testable. Alternatively, the data may simply represent a picture of households who like TAVs more: they grow more varieties, eat them more, and use them more as medicine. The model did control for attitudes to try to remove household affinity for TAVs from the association, but the attitude score is probably an imperfect proxy for the omitted variable of TAV affinity.

In Kiambu, the same correlations were not seen. It may be that people in Kiambu are less familiar with wild varieties, and initially adopted only a few improved domesticated varieties. Because of the short history of TAV use there, less association is expected between diversity and consumption; fewer varieties are known. This is reflected in the histograms showing number of varieties grown in excess of the TAV species produced; in Kiambu the mean was 1.2 additional varieties, and the distribution was less variable (max 5 additional varieties), compared to Arusha where the mean was 1.9 (max 9). One significant relationship in Kiambu was that children consumed more amaranth if the variety was "improved" rather than a wild local variety. The same association was not significant in nightshade, however, although it was expected for all TAV crops based on information discussed in the FGDs.

The "improved" varieties are considered domesticated because they require more human care to thrive - because they are larger, softer, and sweeter they are also less resistant to pests (a characteristic the farmers did not like). As such, they require pesticides or other pest management strategies in order to thrive, while their wild relatives do not. As a general rule, bitter plant compounds of many chemical classes - such as alkaloids, sesquiterpene lactones, glucosinolates - are plants' defense system to fight off pest and pathogen attack. People have exploited these bioactive compounds as medicine; virtually all medicinal components of plants are related to pest/pathogen defense from the plant's point of view. So there are two major reasons, besides variety and acquired taste, that farmers would retain wild-type varieties of a vegetable: for better pest resistance, and for medicinal use.

As discussed in chapter 4, change in medicinal knowledge was significantly related to increase in TAV consumption, suggesting a possible causal link: that when households know TAVs can be useful medicinally, they begin to consume more of them. If households know that the wild varieties are the ones which can be used most effectively for medicinal purposes, then the continued presence of wild varieties would be an important factor in increasing consumption of these vegetables.

Therefore, the goal of the TF or any other project should not be to replace wild varieties with newer varieties, even if they have higher micronutrient content or bioavailability gram for gram. A replacement orientation may run against the reality that people will consume more TAVs overall if wild varieties are maintained, for a variety of reasons including taste, desire for variety, medicinal use, and pest resistance. The new varieties also appear to have some unique benefits; while the old varieties seem to be important to adults' use patterns, the new varieties may be particularly important to encourage children's vegetable consumption. The goal of projects promoting these crops should be to *add* new domesticated varieties to the system, rather than *replace* the varieties already in use.

The idea of addition, rather than replacement, can apply to many agricultural interventions. Without understanding the social behavioral context of crop use, it may be counterproductive to promote single varieties over diversity, even if those single varieties stand out in one particular nutrient. Other factors - taste differing between household members, pest resistance, and specific medicinal or cultural (cuisine/recipe) use - may favor greater overall amount consumed when there are several varieties present.

In addition, as is shown by the nutrient analysis of several varieties of amaranth and nightshade, no one variety stands out as the most nutritious overall. Of course, there is a variety with the most iron - but that is not the same variety as the one with the most provitamin A, and neither of those is the same variety as the one with the most folate or the one with the most antioxidants. In some cases the differences are trivial, but in others they are substantial, with one variety having more than twice the amount of a specific nutrient or phytonutrient as another. It is almost as if each variety is a different vegetable entirely, and it is known that greater botanical diversity is linked to a host of beneficial health effects [295, 294]. The available data are limited to the 8-12 nutrient and phytonutrient components that are well characterized; they say nothing about phytochemicals which are as-yet undiscovered, the leaf matrix affecting bioavailability, nor about the interactions between the nutrients and anti-nutrients contained in the leaves. If other health-promoting components were available to be included in the comparisons, there would likely be even more apparent differences between varieties.

The take-home message from the nutrient data is, whenever one nutrient is maximized there are bound to be trade-offs with other nutrients and phytonutrients. There will never be one "best" variety for all nutritional aspects, let alone taking into consideration the above-discussed behavioral patterns that affect amounts consumed by various members of the household due to taste, growing or cooking qualities, medicinal uses, or pure desire for variety. It is certainly possible to maximize one target nutrient, such as vitamin A or iron, in a single crop variety, which may be useful in certain circumstances of specific deficiencies. However to maximize overall nutrition, diversity is an under-recognized and underutilized strategy in the agricultural and nutrition research world. Maximizing nutritional quality of crops includes both recognizing the unique contributions of existing varieties to nutrition as well as adding new varieties.

The importance of recognizing and adding to existing diversity may differ by context. In places where the crop is a well-established part of culture, as in Arusha, diversity is likely to play a very important role in consumption. It would be important to work with, rather than against, varietal diversity when promoting a specific crop, because households may have a highly specialized needs and wishes for several unique varieties at once. In places where a crop is relatively novel, protecting varietal diversity may be less crucial at the outset, simply because there may be fewer varieties in use to protect. That is not to say that promoting a variety of crops would not have a benefit - according to the diversity of nutrients maximized by different varieties, it might - but it is perhaps less important than where the use of many different varieties for different purposes is already ingrained in behavioral patterns.

Marketability and agronomic characteristics, particularly yield and pest resistance, are also important factors for farmers choosing varieties to cultivate. Neither yield, nor taste, nor marketability, nor nutrition is the whole story explaining why certain varieties are used. In reality, using several varieties may best satisfy all household preferences and needs, and the whole effect of diversity in TAV production systems most likely equals more than the sum of its parts.

7.4.2 Study limitations and future research

These results are intriguing but not conclusive, due to the nature of cross-sectional associations. The correlations shown may be confounded by endogeneity, because households who prefer TAVs in general (an unmeasurable characteristic) may grow and consume more varieties and may also consume them more often. Further panel data research would be helpful to test what happens to consumption when farmers add new varieties to their fields. It might also be interesting to test whether people would consume more vegetables if they were served TAV mixtures with their ugali, compared with single TAV preparations. That is, if the element of choice in food preparation were removed, would diversity in a single meal encourage consumption? If people were given several varieties to cook over the week, would they consume more than if given only one variety?

A limitation of this study is that the number of varieties pictured in the questionnaire was limited, and respondents' interpretation of the pictures was not exact. It would be wrong to conclude that from these results that only five or six varieties of each vegetable are used in these areas. That was the number of varieties pictured, and respondents tended to choose the picture that looked most like the variety they used. When respondents selected a picture, the correct interpretation of their selection is "that variety or one that looks similar" rather than "that variety exactly." The pictures are fairly representative of whether the variety was domesticated or wild, since the domesticated varieties look notably larger, but even there, there was some misinterpretation of the pictures: 12 people reported collecting domesticated varieties from the wild, which is probably not true. Many of the wild varieties look similar, and many more are in use than just the ones shown on the picture cards. There are 50-80 known accessions of different amaranth varieties in the national genebank and herbarium of Tanzania [288], and at least 43 varieties of nightshade in the genebank of Kenya [60]. The use of the term "varieties" in this study certainly cannot imply distinct genetic lines. The way farmers discussed varieties and the way they were measured was based on general characteristics such as leaf size and color, which are not specific enough to identify distinct varieties such as those that would be held in a genebank. If it had been possible to gather information on truly distinct varieties, this analysis would have been more precise.

The fact that TAV-growers are oversampled should not harm the validity of the results, since the results apply to farmers who choose to grow TAVs in any case. The fact that farmers who decided to join a program were oversampled may present a bias, though it is unclear how motivation to join a program would be related to results. It may reflect either greater general household stability or, conversely, greater desperation for improvement in livelihoods. Because of potential bias, with unknown consequences for external validity, these research questions should be explored in non-program contexts.

7.4.3 Conclusions

Does diversity play an important role in the nutritional contribution of TAVs? These results, using a case study of two highly diverse vegetable crops, are a first step towards understanding the complex relationship between within-crop diversity and human nutrition. This relationship is typically either ignored or mythologized, and it is important to collect and analyze data which can begin to show evidence as to the nature of the relationship. The results presented here indicate that at least in some contexts, there does seem to be a link. Household behavior is an important factor. As a general rule, people tend to consume more of a certain food when there are more varieties of it available [126], and this appears to apply to traditional African vegetables as well as jelly beans. This hypothesis should be tested further, because the correlations in this study are compromised by endogeneity. The nutrient data show that different varieties of each crop may offer different nutrient bonuses, and consuming several varieties may allow the eater to benefit from them all. Diversity also appears to be central to the medicinal use of plants, which itself may well be important to nutritional status.

In the case of traditional African vegetables, there appear to be potential nutritional benefits associated with diversity. In a program context where these vegetables are promoted, it is important that the attitude of program staff be one of inclusion of existing varieties, as well as offering of new domesticated varieties. Varietal diversity is an underutilized tool that could be useful toward the overall goals of promoting consumption of specific crops and improving nutrition.

Given the suggestive results of his analysis, and the reality that little other evidence exists, it would be prudent for varietal diversity to become a greater part of thinking in developing interventions aiming to influence nutrition, and for more research to study the links between varietal diversity and nutrition. Some investigators have suggested using indicators of diversity in nutritional surveys [133]. Measurement of a concept helps to ensure that it is not forgotten, which may be a useful first step. Interventions aiming to improve nutrition through biofortification should do a careful analysis of impacts of promotion strategies on varietal diversity, and promotion messages should be inclusive of the value of existing varieties.

CHAPTER 8

CONCLUSION

The main goals of this research were to evaluate the effect of an agricultural program on diet and nutrition of participating smallholder farmer households, and to examine broader questions of how traditional knowledge and crop diversity are related to smallholder farmers' diet quality. Several over-arching conclusions arise from the results described in previous chapters.

8.1 Summary of the program evaluation

The design of the Traditional Foods (TF) Project and its evaluation was described in Chapter 2, along with evidence to evaluate program delivery. The TF Project aimed to increase production, marketing and consumption of TAVs to improve smallholder farmer households. It was made up of four main intervention components: agronomic training, group formation and market linkage formation, nutrition-focused marketing to consumers, and provision of nutrition training about the vegetables to the farmers. Program planners expected that the intervention would increase production, marketing, nutrition knowledge, and favorable attitudes of TAVs, which would in turn result in increased consumption of TAVs within the farmer households. Program theory also rested on the idea that increased production and marketing would increase farmer incomes, particularly among women, which would lead to better overall diets and nutrition, including for young children.

Based on the activities implemented in the first year of the program implementation, as well as barriers and facilitating factors, it was expected that the follow-up evaluation would show increased production and more favorable attitudes of TAVs, that nutrition knowledge would increase somewhat, and that the marketing increases would not yet have taken place for the majority of participating households. Therefore TAV consumption would likely have increased at follow-up based on production and attitude shifts, but changes in income and overall diets would probably not be observed in the program group as a whole. Program impacts were expected to be stronger in Kiambu than in Arusha based on overall stronger implementation in Kiambu, including an earlier start of activities (Chapter 2).

TAV production did appear to have increased among program participants between baseline and follow-up, according to analysis of the data collected (Chapter 5). During focus group discussions held at follow-up, participants frequently asserted that production had increased. Survey results showed that the number of TAVs planted increased only among participants, and not among non-participants or baseline participants (Chapter 5). Harvest amounts appeared to increase among both baseline-only participants and active participants compared to non-participants, but the differences were not significant due to large standard errors and small sample sizes. In agreement with the TF Project program theory, increased production was associated with increased TAV consumption in Kiambu (Chapter 3). Increased TAV production was also associated with increased farm diversity in Kiambu (Chapter 5), which turned out to be an important result related to overall diet.

Attitudes about TAVs also improved in both program and non-program villages in Kiambu, reflecting the broad reach of image promotion campaigns (Chapter 3). More favorable attitudes about TAVs were significantly associated with increased TAV consumption in Arusha in longitudinal quantitative analyses. Qualitative evidence suggested that attitudes were related to consumption in both sites; the attitudes measure may have better captured the construct in Arusha than in Kiambu.

Micronutrient knowledge about TAVs increased marginally, dependent on caretakers having higher education (Chapter 3). Contrary to the program theory, however, micronutrient knowledge change was not associated with increased consumption. Perceived medicinal value of TAVs, although it was not contained in the program theory, was significantly associated with increased consumption in both sites. In Kiambu, increased consumption was related to increased number of unique illnesses the household reported could be treated with TAVs. In Arusha, the main increase in medicinal knowledge was about treatments for iron-related illness including anemia, which may have arisen from iron messages (Chapter 4). Therefore, the utility of micronutrient messages to change behavior may have rested on how well program staff related nutrition education about iron to pre-existing knowledge about TAVs as a treatment for anemia. Based on observation of the staff in the field, the connection between iron and treatment of anemia was often made.

As expected, increases in income due to TAV marketing were not observed in either site, but analyses suffered from large standard errors and very small sample sizes. The fact that sample sizes were so small, however, itself indicated that very few households sold TAVs. For the program to meet one of its main goals of increasing marketing and farmer income, significant work remained to be done after the first year of implementation.

Due to the lack of observable program impact on TAV marketing, change in overall diet was not expected based on the program theory. Indeed, program participants and non-participants alike showed no change in diety quality measured as dietary diversity. As discussed in Chapter 5, the lack of improvement in dietary diversity, however, was mostly due to low potential to benefit rather than slow marketing progress. The study population had quite diverse diets at baseline - the mean, median, and modal dietary diversity scores were well above cutoffs used in other research and programs. Dietary diversity was not an indicator that could have shown changes in dietary quality in this population regardless of the program success.

Other indicators of dietary quality, for which the study population had greater potential to benefit, did show some relationship to program participation. As shown in Chapter 5, program participants significantly increased their consumption of iron-rich foods compared to non-participants, probably through either increased TAV consumption or improved reported overall economic well-being. Among those who increased TAV production, fruit and vegetable consumption increased. Furthermore, participants were significantly more likely to report improved economic well-being compared to baseline, which was significantly associated with greater diversity of household food purchases, which in turn was associated with dietary diversity and dietary variety. Participants were also more likely to increase TAV production, which was directly associated with cultivated crop diversity, which was associated with dietary diversity and dietary variety. Finally, in this study population, dietary variety was significantly positively correlated with weight for age of children age 2-5 years.

Overall, the question behind these analyses was, did the agricultural program affect diet and nutrition? Program participation clearly appeared to affect TAV consumption, which itself is hypothesized to be directly nutritionally beneficial, since it would probably add micronutrients to the diet. Although direct impact of the program on overall diet quality and nutritional status was not observed, examination of the program theory through program impact pathways revealed important dietary effects of intermediate indicators.

8.1.1 Program Impact Pathways: a needed evaluation tool in agriculture-nutrition research

A current priority in global nutrition is to identify not only what interventions to implement, but how to deliver programs that work [150, 234]. The TF Project evaluation results underscore the usefulness of evaluating program theory [216], also called program impact pathways (PIP) [170, 191], to answer the question of how agriculture program can be carried out to have the highest likelihood of improving nutrition.

Program theory can be evaluated in two ways. One is by examining the resources, motivation, and skills of staff and understanding the nuances of *how* program staff frame and deliver program components and messages. This type of program theory evaluation has been best described in behavior change literature [88, 52]. The other is by testing the proof of concept of the program impact pathways to answer the question, does the program theory work? This type of program theory evaluation is similar to plausibility analysis [282]. In research on how agricultural interventions affect nutrition, both are important.

Regarding the first type of program theory evaluation, the resources available to staff, described in Chapter 2, affected the extent to which the program was delivered. Understanding which program elements were actually delivered in the TF Project was important to avoid coming to the wrong conclusion that the marketing intervention failed. The correct conclusion was that it had not yet been delivered and therefore could not be expected to have an effect. Inputs that affected production, knowledge, and attitudes were delivered sooner, and could be evaluated. The evaluation established that while staff were limited in resources, particularly in Arusha, all staff had an extremely well-aligned understanding of the program theory and their role in it. Program staff also had identifiable skills which clearly contributed to the impact of their activities. For example, an important factor related to shifts in attitudes among farmers was the engaging and persuasive communication skills of the program staff (Chapter 2). In a way, dependence on program staff skills makes behavior change interventions difficult to scale up. Yet it is possible to identify elements of that skill which are teachable. Four skills that the TF Program implementers had in common, and which seemed essential to the effectiveness of the program, were public speaking skills, listening skills, respectful attitude towards the beneficiary communities, and purposeful integration of pre-existing knowledge in the community into nutrition and agronomic training. When attempting to scale up a program pathway that worked, it is important that such nuances of staff skill and message delivery be retained.

The previous chapters also showed that important program effects would have been overlooked if the analysis had not also tested the steps along the program impact pathways. When program impacts are less impressive than hoped, as they frequently are, it may be due to intervening factors specific to the implementers, participants or the time and circumstances in which the program was implemented [191]. Without examining the impact pathways, it would be inappropriate to deem the program theory generally ineffective or unworthy of replication. Limiting the analysis to dietary and nutritional status changes in program vs. comparison groups would have shown blunted impact. The main reason is that getting from program participation to improved nutritional status involves many behavioral choices and intervening factors.

The tendency of potential program effects, based on program theory, to be diluted at each successive step between inputs and impacts, could be termed *impact leakage*. Impact leakage would cause average impacts to become increasingly smaller and harder to observe, the more steps there are within the program theory between inputs and impacts. As is shown in the conceptual framework in Chapter 2, there are many steps between TF Project inputs and nutritional status of children.

One way to show impact in programs likely to have substantial impact leakage, such as agriculture-nutrition programs, is to greatly increase the sample size. This could increase the chance of observing small average impacts, and would also allow disaggregation by fine categories of program participation to test for behavioral effect modification. As was seen in several analyses in Chapter 5, impacts were greater among active participants than baseline participants who only received some of the trainings and messages. If the sample size had allowed further disaggregation of the active participants into a finer categories of participation, it is possible that those who participated the most would have had the greatest magnitude of change in impact indicators. As is often the case in program evaluations, however, it was not possible to collect data on a large enough sample size to overcome impact leakage, due to a finite number of program participants, as well as finite time and monetary resources.

For evaluations to show impact of complex and participant behavior-dependent programs, they should not masquerade as simple tests of whether the final impact indicator differs in program vs. control groups [282]. Program impact pathways must be examined to glean the important insights about what worked and did not work in the program. This idea has been discussed and used for supplementation and integrated nutrition programs [155, 169]; it is even more important to apply in agricultural interventions, where there are even more steps and modifying factors that intervene between program delivery and impact on nutritional status. To date, the best evidence for an agricultural program to show a definitive impact on nutritional status has been shown in promotion of a single crop (orange-fleshed sweet potato) rich in a single micronutrient (pro-vitamin A), on a single nutritional status indicator (serum retinol) [156]. That study clearly documented program impact pathways which were relatively straightforward, the design being is as close as an agricultural intervention can get to a supplementation program. Agricultural development over a broader range of crops to improve a broader range of nutritional outcomes would seem to be useful, but hard evidence between agricultural programs and nutritional status outcomes is scant and inconsistent. Substantial impact leakage, and insufficient attention to program impact pathways, explain why.

This research builds on existing evaluation literature by applying analysis of program impact pathways to a multifaceted agricultural intervention, and showing that it yields important insights into the value of the program for nutrition. In this study, the PIP analysis affirmed that economic well-being, food purchase diversity, and crop diversity do have impacts on dietary diversity and variety, and that dietary variety is related to nutritional status. If agriculture programs aim to affect those intermediate outcomes, they may have a better chance of improving nutrition.

8.2 Novel findings: Underutilized tools for improving nutrition

In addition to the use of program theory to evaluate this study, several novel findings emerged from examination of broader questions around medicinal knowledge and crop diversity. The conclusions that emerged are not usually considered in nutrition interventions but may be important to their success.

First, perceived medicinal value of TAVs was found to be a strong motivator for TAV consumption (Chapters 3 and 4). Importantly, knowledge of micronutrient content of the vegetables was not shown to be an important factor motivating consumption. Although the program aimed to increase consumption based on increasing nutrition knowledge about TAVs, it appeared to be particularly important to link new information to pre-existing knowledge within the communities, a principle which has been shown elsewhere in nutrition behavior change literature [52]. This study highlights the importance of specific inquiry about *medicinal* use of foods, particularly vegetables, because such uses may be closely related to micronutrient content or healthy dietary patterns, and can provide an entry point for effective behavior change communication.

Secondly, as shown in Chapter 6, crop diversity was strongly correlated with better diet quality, measured as dietary diversity, dietary variety, servings of vitamin A-rich foods, servings of iron-rich foods, and number of fruits and vegetables consumed. A causal effect is plausible because of qualitative evidence that confirmed that farmers eat what they grow, and that it is time and labor intensive to procure fresh fruits and vegetables if they are not produced on farm. Furthermore, greater crop diversity was associated with greater diversity in home-produced food consumption, but had no association with purchased food consumption. Further research is needed to explore the links between crop diversity and nutrition through the pathways of home consumption, income security, and women's income control.

A third important finding was that varietal diversity could be a factor in consumption of a specific food crop among farmers. It is well-accepted that variety in processed foods spurs increased consumption [286]. This study generates the hypothesis that the stimulatory effect of variety on consumption may operate on farms as well as in buffets and grocery stores. Preliminary evidence shown in Chapter 7 supports that hypothesis, and suggests the need for further research.

Qualitative data in Chapter 7 show definitively that in the study populations, varietal diversity was important for many income and consumption-related reasons. Biochemical data indicate that different varieties also have different nutritional strengths, and a single most nutritious variety of amaranth or nightshade cannot be identified from among the several varieties tested. Similar to the principle of adding new nutrition knowledge to pre-existing knowledge, it may be beneficial for nutrition for agricultural programs that introduce new varieties to avoid replacement of existing varieties.

Finally, an important conclusion of this study was that markets matter for diversity, which carries slightly different implications for nutrition than to say that markets are important for farmers to be able to increase their incomes. If markets can be created for diverse crops and varieties, that is one way to avoid nutritional extinction of species. Policies and programs aimed at biodiversity conservation as well as nutrition and income goals cannot ignore demand creation among consumers. Viable markets for underutilized crops can sustain traditional food and traditional knowledge, and provide the major motivation for farmers to produce those crops.

8.3 Indicators for evaluating nutrition-related impacts in agricultural programs

The research presented points to indicators which could be used in agricultural programs to integrate awareness of nutrition and to demonstrade nutrition-related impacts. The selection of indicators relates to PIP analysis. Child nutritional status indicators such as stunting are good impact indicators for agricultural programs to aim for, but other nutritionally-meaningful indicators exist along impact pathways.

Closely related to nutritional status, dietary diversity is a useful indicator for agricultural interventions to incorporate. It corrects the misunderstanding of food security as merely having access to adequate calories, and can therefore serve to align programs better with activities that will achieve true food security [103]. As discussed in Chapter 5, however, using dietary diversity as an indicator of diet quality can be problematic if the population already has relatively high dietary diversity at baseline. In populations undergoing the nutrition transition, dietary diversity is likely to be high and relatively static regardless of short-term changes in household resources. In such populations, dietary variety and fruit and vegetable variety may be better indicators of diet quality.

Other indicators further removed from nutritional status are nonetheless appropriate nutrition-related indicators for agriculture programs. Crop diversity, if it is associated with dietary diversity as indicated in Chapter 6, is one such indicator. If the agricultural program aims for income increases, food purchase diversity is another (Chapter 5). Women's control of income is likely important to nutrition outcomes, although this research was underpowered to observe evidence of that association. Although it was not explored in this research, the effect of agricultural interventions on women's time may also be important, because it is related to child care and feeding practices - however, easily measurable indicators for women's time use do not exist at present.

8.4 Broader vision: Impacts on food systems and ecosystem services are relevant to nutrition

The discussion of nutritional impact of agricultural programs should not be limited to household- or individual-level indicators. Implications for food systems and ecosystems are arguably as important to nutrition.

When the topic of nutrition effects of leafy vegetables arises, the first question is usually about whether leafy vegetables are actually good sources of micronutrients. Some international nutrition research has pointed to the possibility that nutrients from leafy green vegetables are hardly absorbed [44, 173], while at the same time a substantial body of nutritional research has been built up about the benefits of animal-source foods, particularly meat and milk, for undernourished populations [48, 180]. The balance of research and evidence in the international nutrition literature on promoting animal-source or plant-source foods for nutrition in *developing* countries is not consistent with the kinds of foods and evidence generated for good nutrition in *developed* countries. With formerly-called "diseases of affluence" rapidly growing all over the world, it would seem that the pertinent questions are those of overall food systems and diet patterns rather than debating which individual foods are ideal vehicles of individual micronutrients.

This program evaluation, as laid out in Chapters 2 and 3, takes the stance that the question of how bioavailable vitamin A is from spinach is not the most relevant question to the evaluation of how promoting traditional African vegetables affects nutrition. More important is, how does the intervention contribute to healthy diet patterns in general (as explored in Chapter 5), including maintenance of ecosystem services which are the source of the raw materials for healthy diets.

Growing TAVs saves them from nutritional extinction [124], and promoting TAVs prevents gustatory subversion [152]. The program helps to conserve a traditional food culture which could help stem the increase in obesity and chronic disease due to dietary transitions. Growing TAVs also supports the overall need to make fruits and vegetables more accessible in sub-Saharan Africa. Finally, growing TAVs may increase crop diversity, which itself may be closely related to increased dietary variety. All of these are more nutritionally important rationales for promoting TAVs than using them as micronutrient delivery tools; they capture the emerging imperatives of global nutrition.

8.4.1 Solving undernutrition while not worsening overnutrition

Counterbalancing undernutrition and overnutrition can be done through dietary diversity, particularly increasing botanical variety in diets. This research did not set out to prove the link between dietary diversity and nutritional status, as other research has contributed substantial evidence for that association. (Still, the relationship between dietary variety and child weight-for-age was observed in this study population as well.) Rather, the goals of the intervention described are predicated on the general knowledge that a diverse diet including an abundance of plant foods is good for nutrition and health in the short and long term. A more basic nutrition understanding than that is hard to find, and is recommended worldwide [293, 278, 187].

This basic nutritional goal - diverse diets and abundant plant-source foods - should not be lost across borders. Although emergency and therapeutic nutrition measures are needed in many cases in developing countries, basic advice about the nutritional value of diverse, plant-rich diets is not substantially different based on national GDP. The relevance of this goal becomes particularly apparent when working with a population which is not stereotypical of sub-Saharan Africa; that is, a community of farmers with abundant resources to grow food, cases of visible overnutrition, and in danger of losing biocultural traditions that could sustain healthy diets that already exist.

8.4.2 Food systems must maintain ecosystem services

The chapters less directly addressed the issue of maintaining ecosystem services, but links are apparent. Provision of wild foods is a service of a functioning ecosystem service that can benefit human nutrition through food and medicine. As seen in Chapters 3 and 4, the medicinal use of vegetables appears to be related to their consumption as foods. This insight is very important to nutrition programs, partly because it is almost never considered, yet was the largest predictor of both production and consumption of traditional vegetables that this study found. Nutrition behavior change could potentially have a much larger impact if it had a stronger foothold in cultural traditions and local knowledge, as well as available resources such as traditional foods.

Biological diversity, in agroecosystems (Chapter 6) and within species (Chapter 7), is a critical ecosystem service. The program described in this study was a positive force for improving ecosystem services merely by virtue of conserving the use of crops that could have been destined for nutritional extinction. Eco-agricultural research has catalogued benefits to ecosystems and increased resilience based on diversity [7, 207, 226, 128]; that research has yet to be well-connected to human wellbeing directly through nutrition. The fairly consistent positive correlations observed here between diversity, at both species and variety level, and dietary patterns consistent with good nutrition, provides novel and much-needed evidence that nutrition and environmental goals align. With direct evidence that human health benefits from ecosystem services, there is a better chance that they will be conserved, for the long-term benefit of our species and the planet.

8.5 Future research needs

As presented in this document, there is a strong case for how activities promoting traditional foods can positively affect food systems and nutrition while maintaining ecosystem services. A robust evidence base for the connection between ecosystem services, including agricultural biodiversity, and nutrition is currently lacking, however. This is a case where absence of evidence is not evidence of absence; it is a research agenda which is simply needed to inform food security programs and policies. The research presented here is a small contribution to that need. More global nutrition research is called for to draw connections between food systems, the ecological resource base, and human wellbeing.

The largest research need identified in this study is the need for further evidence about the relationship between crop diversity and diet quality. Diet quality can be measured with indicators that are important for both undernutrition and overnutrition. Such indicators include dietary diversity, dietary variety, and botanical dietary variety. It is also important to better understand the associations between agricultural diversity and income security, seasonal food insecurity, and women's income control; and ultimately nutritional status. More precise measures of agricultural diversity than were available in this study should be used preferentially, such as direct observation of crops cultivated at the time of interview. Studies to examine the associations between crop diversity and nutrition could be done in the context of other agricultural programs in sub-Saharan Africa, as well as in other regions. The South Asia region is another place where many smallholder farmers are at risk of malnutrition, and nutrition-sensitive agricultural research and development are needed.

Within-crop diversity also may be nutritionally important, and to date has not been carefully considered in agriculture programs that aim to improve nutrition. Prospective studies of varietal diversity and consumption are needed to test the hypothesis of whether the "buffet effect" exists on the farm. In a related vein, better food composition data, for different varieties grown in different conditions, would be helpful to document ranges of nutrients that exist within the same crop.

Finally, evaluations seeking to establish an evidence base for the effect of agricultural interventions on nutrition would benefit from greater use of a program impact pathways approach. Evaluating impact agricultural programs on distal nutritional status outcomes, in situations where many behavioral choices and exogenous factors intervene to cause substantial impact leakage, may be less informative than establishing plausible impact pathways and testing each link on the path. There is ample room for the current evidence about agricultural impacts on nutrition to be deepened. The research agenda to expand evidence would include testing and refinement of the indicators suggested for nutrition impact of agricultural programs (dietary diversity, crop diversity, food purchase diversity, women's control of income, women's time use). Stronger evidence and indicators are needed to shape agricultural programs in a way that positively affects nutrition.

Appendices

APPENDIX A

A.1 Collaborating institutions

The **International Potato Center (CIP)** [www.cipotato.org], a member of the Alliance of CGIAR centers with the global mandate to improve sweetpotato production for the tropics, coordinated the project through its regional office in Kenya. CIP developed and successfully implemented a Participatory Market Chain Approach (PMCA) to stimulate value chain development in Latin America. In this project, Wachira Kaguongo, an agricultural economist and Jan Low, Regional Leader and agricultural economist, were involved in the design and implementation of the monitoring and evaluation system, cost-benefit analysis, and the impact assessment research (quantitative and qualitative).

Farm Concern International (FCI) [www.farmconcern.org] is a regional market development trust developing pro-poor marketing models and strategic alliances with the aim of enhancing the competitiveness of the poor in the market place. Janet Mwangi, a full-time experienced market supervisor, led the intervention component, and a full-time CV agent in each site coordinated the farmer groups.

AVRDC-The World Vegetable Center is an international, autonomous, philanthropic, non-profit research and development organization with its headquarters in Taiwan. AVRDC is the principal international center for vegetable research and development. Its mission is to reduce poverty and malnutrition in developing countries through improved production and consumption of safe vegetables. The AVRDC Regional Center for Africa (AVRDC-RCA) was established in Arusha, Tanzania in 1992 for implementing vegetable research and development activities in sub-Saharan Africa. AVRDC-RCA expertise concerns vegetable germplasm collection and conservation, plant selection, breeding, crop production and processing technologies, and IPM technologies. Mel Oluoch, a specialist in African indigenous vegetables, Drissa Silué, an RCA plant pathologist and Stefan Pletziger, an economist, were the AVRDC-RCA scientists working for this project, focused on the technical aspects of traditional vegetable production systems and socio-economic analysis.

Urban Harvest (UH) was an initiative of the Consultative Group on International Agriculture Research (CGIAR), which directed the CGIAR knowledge and technologies to urban and peri-urban situations and addresses the CGIAR goals of poverty alleviation, food security and environmental management for sustainability. The regional coordinator for sub-Saharan Africa is based at the CIP regional office in Nairobi. UH seeks to contribute to increased food security, improved nutritional status, and higher incomes of urban and peri-urban farmers; reduce the negative environmental impact of urban and peri-urban agriculture and enhance its positive ecological potential, and establish the perception of urban and peri urban agriculture as a positive, productive and essential component of sustainable cities. Nancy Karanja, the regional coordinator of UH for SSA, managed the project partnership on a day-to-day basis and collaborated with FCI in establishing urban-based seed production. Mary Njenga, a social scientist, was responsible for gender mainstreaming.

A.2 Producer training modules in the TF Project

Mandatory minimum package of 15 modules to build capacity of commercial producing groups:

1. Successful group leadership

2. Converting a non commercial group into commercial group
3. Record keeping for businesses
4. Group financial management
5. Collective marketing
6. Analyzing your markets
7. Preparation of a business plan
8. Understanding your customer
9. Understanding your competitor
10. Selling techniques and customer relations
11. Micro-credit and micro enterprise development
12. Gender Mainstreaming
13. Conflict management
14. Group formation and management
15. Four marketing components to consider in your enterprise

A.3 Traditional Foods Project logframe

Traditional Foods Project Logframe

Inputs	Assumptions	Outputs	Assumptions	Outcomes	Impacts
-Improved seeds -Agronomic training modules	-Improved seeds are developed and multiplied on time, and delivered to farmers -Weather or climate conditions do not limit the performance of improved seeds -Farmers will attend the trainings; they will understand and adopt the methods taught in the agronomic training modules	-Increased production of TLVs	-TLVs are acceptable to the household for eating -Children will eat TLVs -Women control production of TLVs	-Increased household consumption of TLVs -Increased consumption of TLVs among children age 2-5	-Improved household diet -Improved diet of children age 2-5
-Commercial Village formation for coordinated TLV harvesting -Marketing and group management training modules -Linkages between farmers and markets/traders	-Program staff are hired -Program staff are motivated to provide timely and engaging training -Extension agents are willing to work with program staff -Farmers will work together in groups -Farmers will attend the trainings; they will understand, and adopt the methods taught in the marketing and group management training -There is a market opportunity for increased TLV sales, (if only production were coordinated and demand were ensured) -Traders perceive a benefit for cooperating	-Increased marketing of TLVs (includes increased sales and decreased transaction costs)	-Demand is high enough that TLVs can be sold and TLV price does not fall -Marketing opportunities are targeted at women	-Increased income from TLVs -More income controlled by women -Increased amount and diversity of food purchases	
-Development and dissemination of nutrition-focused marketing messages	-Nutrition-focused marketing messages will be delivered at the right time in sufficient quantity so that they are seen by consumers -Consumers understand marketing information	-Enhanced knowledge of nutritional benefits of TLVs -More positive attitude toward TLVs	-Consumers care about nutrition -Consumers act on information	-Increased demand for TLVs based on nutritional qualities	
-Training module about the nutritional value of TLVs	-Farmers (particularly women) will attend the training session -Farmers understand the information conveyed in the training session and its relevance to them	- Enhanced knowledge of nutritional benefits of TLVs -More positive attitude toward TLVs	-Farmers care about nutrition, especially for their children age 2-5 -Women have the decision-making power to act on nutrition education -Farmers (particularly women) act on TLV nutrition education	-Increased home consumption of TLVs	

A.4 Pilot project (2003-2006) findings and application to the TF Project

The TF Project builds on a pilot project begun in 2003 by FCI, focused on linking TAV producers to major urban markets. Considerable investment was made in organizing farmers into collective units, increasing farmer awareness about TAVs, identifying formal and informal buyers, and linking farmers to the buyers. Moreover, intensive image building campaigns were conducted to raise consumer awareness of the nutritional benefits from consuming TAVs. Initial results of the pilot project as cited in evaluation reports [178, 63] are impressive: [1]

Sales

- Sales of TAVs in Nairobi and peri-urban markets rose from 31 metric tons per month in 2003 to over 500 metric tons per month in 2006, a 1600% increase, most likely due to promotional efforts led by the project. The supply of 500 tons a month is estimated to meet only 60% of the demand in Nairobi, calling for a further increase in production. Because there is still unmet demand, a scale-up of the project is warranted.
- The vegetables most often delivered to Uchumi supermarket in Kenya were nightshade, spiderplant, amaranth, and cowpeas. For this reason, these crops were chosen for promotion in the TF Project.
- Although prices were higher in supermarkets compared to open markets (Ksh10 vs. Ksh6/bundle, respectively), informal markets still play a large role: at the end of the pilot project, about 60% and 95% of TAVs were sold to informal markets in Nairobi and Arusha, respectively. [2]

[1] Results were so impressive, in fact, that FCI won the World Bank CGAP Pro-Poor Initiative Challenge award in 2007 for its work.

[2] Selling to the informal market has important advantages for small farmers because it does not

Profit

- Farm gate prices increased by 30% in Kenya in the project period. FCI states that advertising nutritive benefits of the products led to a high proportion of that increase.
- The commercial village approach reduced individual small farmers' transportation costs from 67% to 14% of the farm gate price in Kenya.
- Farmers said profitability of TAVs was almost double that of other high value horticultural produce.
- Farmer groups of 20-30 members made over $60,000 on average over two years in Kenya, translating to nearly $3/day/farmer.
- Women reported using proceeds from the TAVs "without interference from their husbands or other family members" [63].

Production

- Production levels of amaranth (29.6 t/ha) and nightshade (23-32 t/ha) in target areas in Kenya approximated those obtained with good agronomic practices (30-40 t/ha for amaranth and 25 t/ha for nightshade).
- Members noted reduced on-farm application of fertilizers and pesticides.
- In Kenya, TAVs mainly displaced cut flowers, snow peas, and French beans. Data were not available for Tanzania, but if any crops were displaced they would likely be different because those are not often grown by small farmers.

Consumption

- At the end of the pilot project, all the 31 groups in the project were growing TAVs both for home consumption and for income, and their perception of TAVs reportedly shifted from that of a subsistence/poor person's food to a commercial crop.

have the quality and timing requirements that formal markets do, and payment is immediate. The informal market serves nearly all middle and lower class consumers, and is unlikely to disappear anytime soon in East Africa [261].

- Participants reported that children most often ate amaranth, and adults preferred nightshade.
- Members in one CV noted decreased disease incidence among children.
- Participants reported that they preferred TAVs to cabbage and kale because they were now aware of the nutritional value of TAVs.
- Participants said that TAV production helped save on household expenditure on food, especially vegetables, since TAVs for household use were easily available. Group members reported using the cash income from TAVs to purchase other foods (flour, sugar) and pay school fees.

The pilot project also encountered **challenges**, which the TF Project will seek to overcome:

- The intervention was largely absent in Tanzania. Because there was inadequate extension and group support, group formation was incomplete and no market linkages were made. Project evaluations failed to note low staff presence in Tanzania, instead citing "non-entrepreneurial culture" of the Tanzanian Wa Arusha people as the main reason for lack of success [63, 178]. This indicates a need to ensure adequate staffing in Tanzania for the TF Project, as well as the need for rigorous monitoring and evaluation.
- There was inadequate water for TAV production during dry season months. Therefore selecting communities with the potential for irrigation became important for the TF Project.
- Seeds were not easily available to some because stockists were far away. This led to incorporation of the seed provision scheme in the TF Project.
- Surplus production in rainy months was not absorbed by supermarkets. This directed the TF Project to promote linkages to informal as well as formal markets.

- Radio promotions were expensive, and were not done in Tanzania. Funds were planned for radio promotions in the TF Project.

A.5 General findings of the rapid appraisal

- Agricultural Production
  - Farmers in Kiambu grow a vast variety of fruits and vegetables (often more than 30-40 crops). Many farmers in Arumeru grow few crops (under 10).
  - The frequency and quality of agricultural assistance farmers receive depends greatly on the responsiveness of the extension agent responsible for their area. This is true in government and NGO programs alike, since both rely on the extension agent for access to the community.
  - Food may be scarce in 2008 because a good harvest is not expected. The months of food scarcity (in Arusha) are Feb-March, when the harvest from Oct-Dec is almost finished.
- Nutritional status
  - Statistics on children's nutritional status (weight-for-age only) is generally only available for children up to 9 months of age, when they receive a measles vaccination. After that, they no longer visit the clinic. This observation by health workers matched with the inability of parents to locate health cards for older children, since the cards are no longer frequently used.
  - At least in children up to 9 months, severe malnutrition seems to be somewhat rare and is found mostly in children who have disrupted family lives (such as a parent absent, parents deceased so children are cared

for by other family members, alcoholism in caretakers). Mild malnutrition (weight for age) is common, and moderate malnutrition is also present.

  - The most common diseases in children under 5 in Arumeru are malaria, acute respiratory infection, pneumonia, diarrhea, and skin problems.
  - Nutritionists in Arumeru hospitals say nutrition used to be a problem only for young children, but now the incidence of diabetes (NIDDM) and hypertension are increasing fast. They are showing up even in poor people. The Tanzanian government requested that district medical officers report cases of diabetes.
  - Underweight among women was sometimes observed, although underweight among men seemed more common. (There is a potential bias in observation due to women's bulkier clothing.) Overweight was the norm among wealthier women.
  - Women in urban areas frequently discussed weight control and desire to know more about how to eat a healthy diet.

- Nutrition knowledge
  - Many women were aware of vitamin A, and some were aware of iron. A few could name foods that contained these nutrients, including TAVs, possibly due to previous information given in the pilot program. In Arumeru, in interviews and focus groups some women cited the need to breastfeed a baby exclusively for 6 months when I said I was there to study nutrition. In the markets, mothers were observed feeding thin corn gruel to young infants and cow's milk out of 0.5-liter water bottles. This suggests that there may be education information campaigns

about aspects of nutrition (such as exclusive breastfeeding) that are not necessarily followed.

  - According to a nutritionist in the ministry of agriculture, seeking good nutrition or a balanced diet is associated with having HIV/AIDS. However, this attitude was not independently observed among community members. This generates the hypothesis that there may be stigma associated with eating "healthy" foods, such as men eating traditional leafy vegetables, and nutrition-focused marketing efforts may do well to be aware of this potential stigma.

- Education and wealth
  - It was observed during interviews with farmers that those with greater wealth tended to be more highly educated, and were more willing to be interviewed.
  - In general, there was a fairly high level of education among the farmers in the program areas. Most men and women had completed primary school (7 years), and some had additional education.
  - Farmers in Kiambu appeared wealthier than farmers in Arumeru.

- Gender and income control
  - The father is expected to pay for children's school fees, although sometimes the mother does.
  - Within households, men usually keep more money than women. Women also keep cash; it depends on the individual whether they hand it over to their husband. For those families where someone is employed, there is often a "family basket."

- TAV consumption
  - Most farmer households in Arumeru eat TAVs frequently, and farmers in Kiambu seem to eat them less frequently. This appears to be correlated to less stigma attached to eating them in Arumeru.
  - Participants in the pilot program in Kiambu noted that their children no longer got sick since the household started producing and selling TAVs. They explained this with two reasons: that the children always had enough to eat, and that fewer pesticides were needed on the TAVs than on other crops.
  - Some people said that TAVs are appropriate foods for women but not men; others had no such gender bias about eating TAVs. Farmers and NGO staff reported that elderly people tend to like TAVs because they grew up eating them, and often children find TAVs too bitter.
- Marketing
  - Supermarkets are an important outlet of sale for farmers in Kiambu, but not in Arumeru. They are more important in Kiambu because of the high number and use of supermarkets in neighboring Nairobi. They are not at all important in Arumeru, where there is only one supermarket that sells few fruits and vegetables, and is across the street from a major outdoor market where a huge variety of fruits and vegetables are available every day. More important outlets in Arumeru are open markets (many of which are highly organized and require regular supply), and possibly hotels and restaurants.
  - TAVs are highly perishable, wilting the same day they are harvested. As such, and because of poor-quality roads and lack of refrigerated

trucks, transport of TAVs to cities other than those in close proximity is currently not possible. Export is not possible for the same reasons, in addition to the fact that people outside of East Africa do not know or eat African TAVs, and creating demand is unlikely. Therefore, development of local markets in peri-urban areas presents the most likely opportunity for success.

– For the open market, farmers or traders sell to wholesalers who very early in the morning sell their stock to retailers. The wholesalers get a lower price than the retailers, but there are two reasons why people still sell wholesale: one is the opportunity cost of time – wholesalers say they can sell everything in just one hour, instead of sitting at the market all day. Another reason is that it is very hard to get a spot in the market; they have to be formally rented, and there is a lot of competition for the space.

– Every single vegetable retailer was female, no exceptions. Males were selling plastic bags, clothes, and other non-food items.

A.6 Survey Questionnaire

Nutrition-focused Marketing of Traditional African Vegetables (TAVs)
One-year follow-up survey

S	D	S L	VL	HH

Instructions: Fill A9-A16 at the household.

A. HOUSEHOLD IDENTIFICATION

Code

A1 District/ Site (S)……………………………………...………….

A2 Division (Kenya only) ______________ *For Tanzania, fill* 0

A3 Sub-location (Kenya only) ______________ *For Tanzania, fill* 00

A5 Village (VL)……………………………………………………..…

A6 Household number (HH)

A7 Commercial Village (CV)……………………………….…..…

A8 Marketing Support Unit (MSU)…………………………....

A9 Name of the household ……………………………………………………… Gender

A10 Name of person responsible for the majority of agriculture ………………………………………………………

A11 Name of caregiver of reference child (or where there is no child age 3-6, Gender

person responsible for the majority of food preparation) ………………………………………………………

A11 Name of reference child (age 3-6 years) ………………………………………………………

A12 Date of birth of reference child (***must be before 1 Oct., 2006 and after 1 Oct 2001)*** __ __ / __ __ / ____
DAY MONTH YEAR

HOUSEHOLD GPS LOCATION

A14 Elevation (METERS)……………………………………

A15 GPS location of household in latitude (LAT)………… S __ __ . __ __ __ __ __

A16 GPS location of household in longitude (LOG)………… E __ __ . __ __ __ __ __

INTERVIEW DETAILS Code

A17 Name/code of enumerator______________________

A18 Date of interview (DD/MM/YYYY)

A19 Language(s) in which questionnaire is administered______________________

A20 Checked by (Name/ code)______________________

A21 Date of checking (DD/MM/YYYY)

____

Signature of team leader Date

A22 Name/ code of data entrant________________

Codes

Site (S)	**Division - Kenya (D)**	**Village - Tanzania (VL)**
	5 Lower Lari	101- Olevolosi
	6 Githunguri	102- Kimnyaki
3 -Kiambu	7 Kikuyu	103- Manyire
4 -Arusha/Meru	8 Kiambaa	104- Mlangarini
		105- Shambarai Burka
		106- Mbuguni
		107- Mzimuni (Nduruma)
		108- Marurani

B. HOUSEHOLD MEMBERS

LIST THE HOUSEHOLD MEMBERS & SEX BEFORE ASKING THE REMAINING QUESTIONS. START WITH THE HH HEAD.

B00	B0A	B01	B02	B03	B04	B05	B06	B08
N°	Name Would you please give me names of the HH members, (people who usually live & eat together in this household) in the past year (beginning in October 2007) Aside from these persons, were there other persons who lived and ate with your HH in the past year?	Sex 0- Male 1- Female	Relation to head 1- Self 2- Spouse 3- Son/daughter 4- Brother/sister 5- Father/mother 6- grandchild 7- nephew/niece 8- Other relative 9- Non relative	How old is [..name..]? (years) *Note: children < 1 yr old have age of 0*	Currently in school? 0- No 1- Yes	If currently in school, what level?	If NOT currently in school, highest level of school completed 0- Illiterate 1-13 14- College 18-Preschool 19- Can read & write	***For members over age 10:*** Does [..name..] practice agriculture as a primary activity? 1- Primary activity 2- Side activity 3- Does not grow crops or breed animals
01								
02								
03								
04								
05								
06								
07								
08								
09								
10								
11								
12								
13								
14								

Note: if a member is in school, just ask if he/she practices agriculture. If yes, mark "side activity".

B08 How many other children do you have apart from those already listed? ☐☐

B081 Did you ever have any children who died? (0- No, 1-Yes) ☐ *If yes, How many?* ☐

B09 What is the marital status of the head of the household? ☐

School level codes

(Kenya)	(Tanzania)
Standard 1 = 1	Standard 1 = 1
Standard 2 = 2	Standard 2 = 2
Standard 3 = 3	Standard 3 = 3
Standard 4 = 4	Standard 4 = 4
Standard 5 = 5	Standard 5 = 5
Standard 6 = 6	Standard 6 = 6
Standard 7 = 7	Standard 7 = 7
Standard 8 = 8	
(Kenya)	**(Tanzania)**
Form 1 = 9	Form 1 = 8
Form 2 = 10	Form 2 = 9
Form 3 = 11	Form 3 = 10
Form 4 = 12	Form 4 = 11
	A level 1=12
	A level 2=13

Marital status codes

1- Single
2- Married (monog), living with spouse
3- Married (polygam), living with spouse
4- Married (monog), spouse not present
5- Married (polygam), spouse not present
6- Divorced/separated
7- Widow/widower

C. FARM ASSETS

RESPONDENT: PERSON RESPONSIBLE FOR MAJORITY OF AGRICULTURE

S	D	S L	VL	HH

Now I am going to ask you some questions about your farm.

C01 What is the total size of the land you own? ___ . ___ ACRES *(1 acre = about 4000m^2) (1 ha. = 2.47 acres = 10,000m^2)*

C02 What is the total amount of land you **rent or borrow from** others? ___ . ___ ACRES

C03 What is the total amount of land you **rent or lend to** others? ___ . ___ ACRES

C04 What is the total cultivated land? ___ . ___ ACRES *(Note: Did the respondent subtract the amount of land where the house and other buildings sit?)*

C05 Does the household have electricity? (0- No, 1- Yes) ☐ C06 Does the household have a latrine? (0- No, 1- Yes) ☐

C07 What is the main source of drinking water for your household? ☐ 1- lake or pond, 2- river or stream, 3-spring, 4-well/borehole, 5-rainfall capture, 6-piped, 7-other__________

C08 How many ________ does your household own?

C09 How many ________ were sold during the past 12 months?

	Cattle A	Goats B	Sheep C	Pigs D	Chicken & Ducks E	Donkey F	Other livestock, specify G
# Owned							
# Sold							

Now I'm going to list some items; please tell me how many of each item are owned by your household.

C11 How many _________ are owned by your household?

(Write the number owned of each)

	Motor-cycles A	Cars/ Trucks B	Tractor C	Bicycles D	TV E	Refrige-rator F	Mobile Phones G	Radios H	
# owned									
	Ox-Plough I	Cart for Transport J	Irrigation Pump K	Shallow/ Tube well L	Sprinklers M	Hand Sprayers N	Wheel-barrows O	Watering Cans P	Axes Q
# owned									

Observation to be made by enumerator:

C14 What kind of **roofing** material does the main house have? ☐ 1-Cement, 2-Tiles, 3-Metal sheets, 4-Wood, 5-Grass/cane/palm leaves (thatch), 6-Other______________

C15 What materials are the **walls** of the main house made of? ☐ 1-Concrete blocks/bricks, 2-Mud, 3-Metal sheets, 4-Wood, 5-Mud/stone/wood mix, 6-Other___________

C16 What material is the **floor** of the main house made of? ☐ 1-Cement/concrete, 2-Mud, 3-Tiles/linoleum, 4-Wood, 5-Other_________________

S	D	S L	VL	HH

D. CROP PRODUCTION

RESPONDENT: PERSON RESPONSIBLE FOR MAJORITY OF AGRICULTURE

Now I am going to ask you about the crops you grow.

D1 **In the past year (Oct 2007-Sept 2008),**

Did you plant any…	0=no 1=yes	***If yes,* Did you sell any?** 0=no, 1=yes
1 Sweet potatoes?		
2 Sweet potato leaves?		
3 Amaranth?		
4 Nightshade?		
5 Spider plant?		
6 Cowpea leaves?		

D2 If farmer is not growing any TAVs, what are the reasons? | | | |

Codes:

1- Never heard about TAV	3- Prefer other vegetables	5- No buyers
2- Lack of TAV seeds	4- TAV do not grow well here	6 Other (specify)_______________

D3 **Which other crops did you grow in the past year (Oct 2007-Sept 2008)?**

Crop	Code	**Do you sell any of this crop?** 0= no, 1=yes	Crop	Code	**Do you sell any of this crop?** 0= no, 1=yes
1			21		
2			22		
3			23		
4			24		
5			25		
6			26		
7			27		
8			28		
9			29		
10			30		
11			31		
12			32		
13			33		
14			34		
15			35		
16			36		
17			37		
18			38		
19			39		
20			40		

After the farmer lists all the crops grown, prompt with staple crops, fruit crops, etc.

D4 **What are the three most important crops for HOME CONSUMPTION?**

Crop		**2008 (April-September)**				**2007 (October-March)**			
Note: If TAVs are mentioned, list it but do not fill in details.	Code	**What was the total harvested in Apr-Sept?** Quantity	Unit	*If bags, how many* kg/bag	State*	**What was the total harvested in Oct-March?** Quantity	Unit	*If bags, how many* kg/bag	State*
	A	B	C	D	E	F	G	H	I
1									
2									
3									

**Note: for maize and groundnut, there may be >1 state.*

D5 **What are the three most important crops for SALE?**

Crop		**2008 (April-September)**				**2007 (October-March)**			
*If TAVs, sweetpotato or cassava are mentioned, list it but do not fill in details. (**Kiambu** : DO fill for cassava)*	Code	**What was the total harvested in Apr-Sept?** Quantity	Unit	*If bags, how many* kg/bag	State*	**What was the total harvested in Oct-March?** Quantity	Unit	*If bags, how many* kg/bag	State*
	A	B	C	D	E	F	G	H	I
1									
2									
3									

**Note: for maize and groundnut, there may be >1 state.*

Units of harvesting		**State of harvesting**	
1=kg	5=Bundles (leafy veg)	1 Fresh	5 With shells (for nut)
2=2 kg tin/bucket	6=Bunches (banana)	2 Grain	6 Without shells (for nut)
3=20 kg tin/bucket	7=Pieces	3 Dry cobs (for maize)	7 Other________
4=bag	8=Other__________	4 Green cobs (for maize)	

D6 **In the past year (Oct 2007-Sept 2008),**

Did you produce any	0=no 1=yes	***If yes,* Did you sell any?** 0=no, 1=yes
1 Milk?		
2 Eggs?		

Note: this table D6 replaces the baseline tables D6 and D7

I. Group Membership, Agricultural Information, Access to Credit

RESPONDENT: PERSON RESPONSIBLE FOR MAJORITY OF AGRICULTURE

S	D	S L	VL	HH

Now I am going to ask you about your group membership and sources of agricultural information

I1 Is anyone in the household a member of a farmer group/agricultural association? (0- No 1- Yes) ☐

I2 Is anyone in the household a member of any other non-agricultural group? *(do not include church)* (0- No 1- Yes) ☐

I3 Does the household have a budget/record book of farming expenses and profits? (0- No 1- Yes) ☐

I5 What are the two most important sources from which you have received information about agricultural prices (crops and/or inputs)?

Codes (0- No source) ☐ ☐

1- friends, neighbors	5- Farm Concern staff	9- Religious group meetings
2- Businessmen	6- AVRDC staff	10- Radio
3- Govt Ag Extension staff	7- Commercial village	11- Going to market
4- Ministry of Agriculture	8- Other farmers' association/cooperative	12- Other____________________________

I6 During the last 12 months, have you received any information about new varieties of vegetables? (0- No 1- Yes) ☐
Note: "new" refers to varieties that are new to the HOUSEHOLD.

I61 If yes, from what source(s)? ☐ ☐ ☐

Codes (0- No source)

1- friends, neighbors	5- Farm Concern staff	9- Religious group meetings
2- Businessmen	6- AVRDC staff	10- Radio
3- Govt Ag Extension staff	7- Commercial village	11- Going to market
4- Ministry of Agriculture	8- Other farmers' association/cooperative	12- Other____________________________

I7 In the last 12 months, has anyone in the household had training from Farm Concern International (FCI)? (0- No 1- Yes) ☐

I71 *If yes*, was the training about.....

1- market-oriented production (0-No 1-Yes) ☐
2- farmer groups (0-No 1-Yes) ☐
3- finance and saving (0-No 1-Yes) ☐
4- inputs (0-No 1-Yes) ☐
5- nutrition (0-No 1-Yes) ☐
6- other (specify)____________________

In Tanzania only:

I8 During the last 12 months, have you received agricultural training from AVRDC? (0- No 1- Yes) ☐

I9 Has any household member received credit in the last 12 months? (0- No 1- Yes) ☐

I91 ***If yes,*** Was the purpose of this credit for agriculture? (0- No 1- Yes) ☐

I10 ***If received credit,*** Among the household members, who received credit? (0- Male 1-Female 2-Both) ☐

I13 Since 2007, has anyone in the household been invited by Farm Concern International (like by Lincoln, Mwangi, Furaha, Irene) to join a farmer group?
If no, skip to section J. (0- No 1- Yes) ☐

I14 *If yes,* Did you agree to join? (0- No 1- Yes) ☐

I141 *If did not join,* Why not? ________________________

I15 *If agreed to join,* Are you still a member? (0- No 1- Yes) ☐

I16 *If NO,* Why not? ________________________

Note: questions I11 and I12 from the baseline are deleted.

J. INCOME SOURCES

RESPONDENT: EITHER PRIMARY RESPONDENT

S	D	S L	VL	HH

J1 Are there certain months of the year when you do not have as much food as you would like to have in the household? (0- No, 1- Yes) ☐

J11 If yes, which months? *(tick)*

OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP

J7 Do you think that your family is in better, the same, or worse economic conditions now compared to last year? (0- same, 1- Better, 2- Worse) ☐

J71 *If it is better or worse:* **Why?** ____________________

J2

During the last 12 months, was any household member active in the following:	(0- No, 1- Yes)
Agricultural work on someone else's farm	
Mechanics or construction	
Working outside the country	
Housekeeping for someone else (cook, gardener, etc)	
Teaching, health services	
Small business	
Other wage or salaried employment ________________	
Other wage or salaried employment ________________	

Note: the rest of table J2 from the baseline is deleted.

J3 During the last 12 months, did any member of this household **receive** food, money or other goods from somebody living outside of the household compound? 0- No 1- Yes ☐

J4 Is anyone in your household receiving a pension? 0- No 1- Yes ☐

J5 Do you have any other source of income other than those already mentioned? 0- No 1- Yes ☐ If yes, specify______________________

J6 Of the sources of income your household has (*repeat sources they told you about*), rank the following **sources of income** in order of importance to your household (*1 is most important, 2 is second most important…)* :

Sale of vegetables *(D3)*	
Sale of other food crops *(D3)*	
Sale of non-food cash crops (eg tea, fodder) *(D3)*	
Sale of livestock/livestock products *(C9 & D6)*	
Wages or salaries in cash *(J2)*	
Gifts or pensions *(J3-J4)*	
Other (specify)________________ *(J5)*	

Using the last question, clarify that the sources of income marked are the household's only sources of income.

Note: Credit is NOT a source of INCOME.

S	D	S L	VL	HH

K. TAV PRODUCTION & MARKETING (ask only if the farmer is growing any of the TAVs in the table)

RESPONDENT: PERSON MAINLY RESPONSIBLE FOR TAV PRODUCTION

Now I am going to ask you about production of the following leafy vegetables: amaranth, nightshade, spiderplant, sweet potato leaf, and cowpea leaf.

K1 Who in your household is mainly responsible for production of these leafy vegetables? (0-Man, 1-Woman, 2-Both) ☐ ***(This person should be the respondent for sections K-L)***

K011 Has this changed since last year? (0-no, 1-yes) ☐ K012 *If yes,* Why?____

K2 For how many years have you grown these vegetables? ☐ K3 In which months do you grow them?

YR ROUND	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP

K4 **For the last season (April-Sept 2008),** *Note: If farmer cannot estimate area, at the end of the interview, pace around the TAV plots to estimate area.*

	A	B	C	D	E	F	G	H	H2	H3	I	J	K	L	M	N	O	P	Q	Q2	R
TAV varieties grown	What was area planted last time you planted?	1=m^2 2=acre 3=ft^2 4=other	Inter-cropped? 0=No 1=Yes	If yes, with which crop(s)?	**Since April,** how many times have you planted?	How many times did you harvest per each planting?	What was the quantity you harvested **per harvest**?	1=kg 2=bundle 3=kiroba 4-7 (see)	*If 2,* bundles per std box/bag	*If 3,* note kiroba size	Did you sell any of this vegetable?	***If yes*** **Per harvest,** how much did you sell?	1=kg 2=bundle 3=kiroba 4-7 (see)	Where did you sell it? Name of market(s)	1=Farmgate 2=Small mkt 3=Big mkt 4=Supermkt 5=Roadside, 6=other	What proportion did you sell there?	At each market, what price did you sell for?	1=kg 2=bundle 3=kiroba 4-7 (see)	*If 2,* bundles per std box/bag	*If 3,* note kiroba size	Did you sell as indiv or group? 0=indiv. 1=group
		Unit		Code		(since April)	volume	Unit	#	kg	(0-no, 1-yes)	volume	Unit	*(to aid enumerator)*	Code	%	price	unit	#	kg	
K41 **Amaranth**																					
K42 **Nightshade**																					
K43 **Spider plant**																					
K45 **Cowpea leaf**																					
K46 **Sweetpotato leaf**																					

K. TAV PRODUCTION & MARKETING (Continued)

RESPONDENT: PERSON MAINLY RESPONSIBLE FOR TAV PRODUCTION

S	D	S L	VL	HH

*If farmer **has not sold any TAV** last season,*

K5 Why did you not sell any of the vegetables mentioned last season?

(Note: this question was just moved from the previous sheet in the baseline.)

1 -Produced enough for home use only	3 -Low prices	5 -Not yet ready for harvest
2 -Lack of buyers	4 -Poor quality produce	6 -Other__________

---

*If farmer **HAS sold TAVs** in the last season,*

K7 *Reconfirm the farmer's **main market** for selling TAVs* ____________________

If you do not know the market:

K8 How far is it from your farm? ___ . ___ km   1 hour walking = 5 km

K9 How do you transport TAVs there?

1 -on head/back	5 -car
2 -wheelbarrow/cart	6 -lorry
3 -bicycle	7 -donkey
4 -public transport (bus/matatu)	8 -other (specify)________

K10 How much do you pay for this transportation, per unit of TAV transported?

(A) Amount	(B) per unit TAV

Unit of production/sale

1 -Kg	4 -Marlboro bag (small)
2 -Bundle	5 -Marlboro bag (med)
3 -Kiroba (note size)	6 -Marlboro bag (large)
	7 -Other__________

K11 Do you pay for transport as an individual or group? (0- individual, 1-group)

For ALL farmers:

K12 **In the last season (April-September 2008),**

		Which varieties did you plant?	Apart from those you planted, did you collect any other varieties?	Of those listed, which varieties do you sell?	Which varieties do you prefer for eating in your own home?
Amaranth *(use pictures)*					
Nightshade *(use pictures)*					
Spider plant *(tick)*	Green				
	Purple				
Cowpea leaf *(tick)*	Spreading				
	Erect				
Sweet potato leaf *(use pictures)*					

L. TAV INPUTS and trade-offs

RESPONDENT: PERSON MAINLY RESPONSIBLE FOR TLV PRODUCTION

S	D	SL	VL	HH

Now I am going to ask you about inputs you used in the last season (April-Sept 2008) on the vegetables we just discussed.

				Note: seeds used in LAST SEASON			*Note: portion used in LAST SEASON ONLY*				*Note: portion used in LAST SEASON ONLY*			
TLV grown	Seed sources		Distance to main seed source	Total price paid for the seeds used	Did you obtain seeds individually or in a group? 0=individual 1=group	Did you use any fertilizer? 0= no 1= yes, organic 2=yes, inorganic 3=yes, both	Total price paid for fertilizer used	Did you purchase individually or in a group? 0=individual 1=group	Did you use any kind of pesticide or herbicide? 0= no 1= yes, pesticide only 2=yes, herbicide only 3=yes, both	If using pesticide, was it: 1=chemical 2=biological 3=both	Total price paid for pesticide and/or herbicide used	Did you purchase individually or in a group? 0=individual 1=group	Irrigation? 0=no 1=yes	Any other input? (if yes, record which)
	A1	A2	B	C	D	E	F	G	H	I	J	K	L	M
1 Amaranth														
2 Nightshade														
3 Spider plant														
4 Cowpea leaf														
5 Sweetpotato leaf														

L6 In the last 12 months, has a neighbor ever asked you for seed/ vines for any of the vegetables you are growing?

	(0-no, 1-yes)
Amaranth	
Nightshade	
Spider plant	
Cowpea leaf	
Sweet potato leaf	

L61 *If yes,* How many neighbors asked you? ☐

L62 *If yes,* Did you give or sell the seed/ vine? (0-give, 1-sell, 2-both give and sell) ☐

Source of seed codes

0 Own
1 Neighbour/family member
2 Demo/Group plot
3 Market trader
4 General shop
5 Commercial seed multiplier /trained farmer
6 KARI/MOA
7 Agro-vet
8 NGO (specify)__________
9 Other (specify)__________
10 FCI/Farm Concern
11 AVRDC

L7 In the last 12 months, in some of your farm area have you replaced another crop with any of the vegetables mentioned? (0-no, 1-yes) ☐

L71 *If yes,* Which crop(s)? ________ ☐ ________ ☐ ________ ☐ *(see crop code sheet)*

Which TAVs replaced it? ________ ☐ ________ ☐ ________ ☐

L8 In the last 12 months, has anyone in your household stopped taking part in a wage job in order to grow any of the vegetables mentioned? (0-no, 1-yes) ☐

L81 *If yes,* Which job(s)? ________ ________ ________

K6 Do you dry any of the vegetables mentioned? (0-no, 1-yes) ☐ *(Note: this question was just moved from a previous sheet in the baseline.)*

M. GENDER ROLES AND DECISION-MAKING

RESPONDENT: MOTHER/MAIN CAREGIVER OF THE REFERENCE CHILD (or person responsible for food preparation)

Now I am going to ask about decisions in your household about the crops we just discussed.

If the household grows TAVs (amaranth, nightshade, spider plant, sweet potato leaf, or cowpea leaf):

M1 Who decides whether to plant the leafy vegetables we discussed? (0- men, 1- women, 2- equal) ☐

M2 Do men and women have separate plots of those leafy vegetables? (0-No, 1-Yes) ☐

If yes,

M21 What is the main purpose of the man's plot? 1-home consumption 2-sales 3- both ☐

M22 What is the main purpose of the woman's plot? 1-home consumption 2-sales 3- both ☐

If the household sells TAVs (amaranth, nightshade, spider plant, sweet potato leaf, or cowpea leaf):

M3 Who markets those leafy vegetables? (0- men, 1- women, 2- both) ☐

M4 What proportion of the income from the sale of TAVs does the woman keep? ☐ %

For ALL HOUSEHOLDS:

M10 In your household, who makes the decisions on major new purchases? (0- men, 1- women, 2- equal) ☐

M11 In your household, who decides what food is purchased? (0- men, 1- women, 2- equal) ☐

M12 In your household, who goes to the market to purchase food? (0- men, 1- women, 2- equal) ☐

M13 In your household, who provides the funds for paying the school fees? (0- men, 1- women, 2- equal) ☐

M14 In your household, who purchases cooking fuel? (0- men, 1- women, 2- equal, 3- cooking fuel not purchased) ☐

M15 In your household, what is the main source of cooking fuel? ☐

1 Firewood	4 Rice/grass husks	7 Gas stove
2 Charcoal	5 Sawdust	8 Electric stove
3 Kerosene	6 Animal dung	9 Other (specify)________________

N. WOMEN´S NUTRITION KNOWLEDGE

S	D	S L	VL	HH

RESPONDENT: MOTHER/MAIN CAREGIVER OF THE REFERENCE CHILD (or person responsible for food preparation)

N7 Have you ever gotten information on the benefits of eating many different foods each day? (0- No 1- Yes) ☐

If no, skip to N1.

N71 *If Yes:* Where did you learn that information? Source(s): ☐☐☐

Codes

1- Friends, neighbors, family	4- TV	7- Farm Concern staff	10 Agricultural extensionists	13 Village leader
2- School	5- Posters	8- Training at AVRDC	11 Health extension staff	14 Religious group meetings
3- Radio	6- Pamphlets/flyers	9- Other TF Project training	12 Doctor, nurse	15 Other________________

N1 Have you heard of Vitamin A? (0- No 1- Yes) ☐

If no, skip to N4

N2 Why is Vitamin A important for us? ____

N21 Where did you learn that information? Source(s): ☐☐☐

Codes

1- Friends, neighbors, family	4- TV	7- Farm Concern staff	10 Agricultural extensionists	13 Village leader
2- School	5- Posters	8- Training at AVRDC	11 Health extension staff	14 Religious group meetings
3- Radio	6- Pamphlets/flyers	9- Other TF Project training	12 Doctor, nurse	15 Other________________

N3 Can you give 3 examples of foods rich in Vitamin A? (1)________ ☐ (2)________ ☐ (3)________ ☐

N4 Have you heard of iron? (0- No 1- Yes) ☐

If no, skip to section O.

N5 Why is iron important for us? ____

N51 Where did you learn that information? Source(s): ☐☐☐

Codes

1- Friends, neighbors, family	4- TV	7- Farm Concern staff	10 Agricultural extensionists	13 Village leader
2- School	5- Posters	8- Training at AVRDC	11 Health extension staff	14 Religious group meetings
3- Radio	6- Pamphlets/flyers	9- Other TF Project training	12 Doctor, nurse	15 Other________________

N6 Can you give 3 examples of foods rich in iron? (1)________ ☐ (2)________ ☐ (3)________ ☐

O-P. OPINIONS ABOUT TARGET CROPS

RESPONDENT: MOTHER/MAIN CAREGIVER OF THE REFERENCE CHILD (or person responsible for food preparation)

S	D	S L	VL	HH

Now I am going to ask for your opinions about traditional leafy vegetables.

O1 Are there any health benefits of consuming TAVs? (0- No 1- Yes) ☐

O11 If yes, what are they? ______________________________

O12 Have you received training about nutrition or health benefits of TAVs specifically? (0- No 1- Yes) ☐

O13 If yes, what did you learn there? ______________________________

O3 Can you use traditional leafy vegetables to treat any illnesses? (0- No 1- Yes) ☐

O31 If yes, which TAVs and which illness(es)?

TAV	illness 1	illness 2	illness 3
Amaranth			
Nightshade			
Spider plant			
Sweet potato leaf			
Cowpea leaf			

O32 Has consuming TAVs helped you or someone in your household with any particular illness personally? (0- No 1- Yes) ☐

O33 If yes, which TAVs and which illness(es)?

TAV	illness 1	illness 2	illness 3
Amaranth			
Nightshade			
Spider plant			
Sweet potato leaf			
Cowpea leaf			

O4 Do you collect any wild leafy vegetables/wild fruits? (0- No 1- Yes) ☐

O41 If yes, please list them:

______________ ______________ ______________
______________ ______________ ______________
______________ ______________ ______________

P8 Do you offer traditional leafy vegetables when visitors come to your home? (0- No 1- Yes) ☐

P1 Some people say amaranthus, nightshade and spiderplant are suitable substitutes for meat. How do you feel about this opinion?

☐ Strongly disagree ☐ Neither agree nor disagree
☐ Disagree ☐ Agree
☐ Strongly agree

P2 William will not eat traditional leafy vegetables because they are not good food for men. How do you feel about his opinion?

☐ Strongly disagree ☐ Neither agree nor disagree
☐ Disagree ☐ Agree
☐ Strongly agree

P3 Sometimes people get sick because they eat vegetables that contain pesticide residues. How do you feel about this opinion?

☐ Strongly disagree ☐ Neither agree nor disagree
☐ Disagree ☐ Agree
☐ Strongly agree

P31 Some people say that amaranthus, nightshade, and spiderplant are "women's crops." How do you feel about this opinion?

☐ Strongly disagree ☐ Neither agree nor disagree
☐ Disagree ☐ Agree
☐ Strongly agree

P4 Would you like to **consume** more, less, or the same amount of the leafy vegetables mentioned, compared to the amount you **consume** now?
(0- same, 1- more, 2- less) ☐

P5 Would you like to **grow** more, less, or the same amount of the leafy vegetables mentioned, compared to the amount you **grow** now?
(0- same, 1- more, 2- less) ☐

P6 Would you like to **sell** more, less, or the same amount of the leafy vegetables mentioned, compared to the amount you **sell** now?
(0- same, 1- more, 2- less) ☐

Q. FOOD FREQUENCY QUESTIONNAIRE

RESPONDENT: MOTHER/MAIN CAREGIVER OF THE REFERENCE CHILD (or person responsible for food preparation)

REFERENCE CHILD (AGE 2-5) Name:____

Now I'm going to read a list of foods. Please tell me in the last week (7 days), how many days did anyone in the household eat each food I list. Also tell me how many days did [..reference child..] eat each food on the list.

Explain to the mother that you want the number of DAYS, not the number of times.

For example, if she gave the child maize and porridge twice on Wednesday it only counts as 1 day.

	NAME OF THE FOOD	NUMBER OF DAYS THE FOOD WAS CONSUMED OVER THE PAST 7 DAYS: ANYONE IN THE HOUSEHOLD (A)	REFERENCE CHILD (B)	Source of food 1= Home produced 2=Purchased 3= Wild/"just grew" 4= Other (C)	OF THE TAVs and SPs THE REFERENCE CHILD CONSUMED, TYPICAL QUANTITY CONSUMED (D) *(estimate using the standard bowl)*	Was the TAV **mixed** with other foods? 0=No 1=Yes	E **If Yes,** out of that mix, how much of the bowl would the specified TAV fill?
1	Ugali (maize/sorghum/millet porridge)						
2	Uji (maize/sorghum/millet porridge)						
3	**Whole** chili pepper						
4	Milk (cows milk/goats milk/powdered/fresh/sour)						
5	Cabbage						
6	Carrots						
7	Ripe mango						
8	Pumpkin						
9	Spinach						
10	Kale						
11	Ripe papaya						
12	Food fried in oil or with oil						
13	Rice						
14	Amaranth leaves						
15	Sweet potato leaves						
16	Nightshade						
17	Spider plant						
18	Cowpea leaves						
19	White flesh sweet potato						
20	Orange-flesh sweet potato (OFSP)						
21	Yellow-flesh sweet potato						
22	Eggs						
23	Fish/small fish						
24	Groundnut or cashew nut						
25	Chicken						
26	Meat (cow/pig/sheep/rabbit..)						
27	Butter or margarine (e.g. Blue Band)						
28	Beans (all kinds)						
29	Cassava - fresh or flour						
30	Packaged juice						
31	Packaged biscuits/cookies						
32	Carbonated soft drink (e.g. Coca-cola, Fanta)						
33	Other Fruits (like banana, orange, etc.)						

Q1 *If TAVs were consumed at least once/week: Please describe the variety you mainly consumed*

	Variety(ies) *Use pictures*			*IF variety is "other", ask:*	0-bitter 1-sweet	0-narrow leaves 1-broad leaves	0-green 1-purplish/red	COWPEA ONLY 0-spreading 1-erect
1 Amaranth				Amaranth				
2 Sweet potato leaf				Sweet potato leaf				
3 Nightshade				Nightshade				
4 Spider plant	→			Spider plant				
5 Cowpea leaf	→			Cowpea leaf				

FOR ALL:
2-both
88- Don't know
99-No preference

If TAVs were consumed at least once/week: Out of the following reasons, why do you regularly consume TAVs? (circle reasons)

Q2 1= taste, 2=price, 3=availability, 4=improves health/nutrition, 5=tradition, 6=other____________________

If TAVs were not consumed last week: Out of the following reasons, why do you not regularly consume TAVs? (circle reasons)

Q3 1= taste, 2=price, 3=availability, 4=pesticides, 5=don't know them, 6=other____________________

If the child did not eat any TAV (amaranth, nightshade, spiderplant, sweet potato leaf, cowpea leaf) in the last 7 days:

Q4 Why did the child not eat TAVs in the last 7 days? ____

R. 24 hour Recall of Consumption for the Household and Specifically for the Reference Child

RESPONDENT: MOTHER/MAIN CAREGIVER OF THE REFERENCE CHILD (or person responsible for food preparation)

R1 In this household, how many times do you normally eat in a day (counting porridge as eating, but not tea alone)? ☐

R2 How many times does (reference child) normally eat in a day? ☐

Now, let us discuss about what your household ate yesterday.

R3 Starting with the first thing you ate or drank yesterday after getting up, list the foods and beverages that were taken in your household

Instructions: if the respondent says something was consumed ONLY by the reference child, write it in box R5 on the next page.

REF #	**Which dish(es) were taken yesterday first thing (breakfast)?** Code				**Which ingredients were used to make the dish?** code				C **Was this item consumed by [*reference child*]?** (0-No, 1-Yes)
	A				B				
1									
1									
1									
1									
1									
1									
1									
1									
1									
1									
1									
1									
1									
1									
1									
1									

REF #	D **Was anything taken yesterday between breakfast and lunch? (like beverages, fruits, etc)** Code				*For any mixed dishes,* E **Which ingredients were used to make the dish?** code				F **Was this item consumed by [*reference child*]?** (0-No, 1-Yes)
2									
2									
2									
2									
2									

REF #	G **Which dish(es) were taken yesterday for at midday (lunch)?** Code				H **Which ingredients were used to make the dish?** code				I **Was this item consumed by [*reference child*]?** (0-No, 1-Yes)
3									
3									
3									
3									
3									
3									
3									
3									
3									
3									
3									
3									
3									
3									
3									
3									

R. 24 hour Recall of Consumption for the Household and Specifically for the Reference Child (continued)

REF #	J **Was anything taken yesterday between midday (lunch) and dinner?**	Code			K **Which ingredients were used to make the dish?**	code			L **Was this item consumed by [*reference child*]?** (0-No, 1-Yes)
4									
4									
4									
4									
4									
4									

REF #	M **Which dishes were taken yesterday for dinner?**	Code			N **Which ingredients were used to make the dish?**	code			O **Was this item consumed by [*reference child*]?** (0-No, 1-Yes)
5									
5									
5									
5									
5									
5									
5									
5									
5									
5									
5									
5									
5									
5									
5									
5									
5									
5									
5									

REF #	P **Was anything taken yesterday after dinner? (like beverages, fruits, etc.)**	Code			Q **Which ingredients were used to make the dish?**	code			R **Was this item consumed by [*reference child*]?** (0-No, 1-Yes)
6									
6									
6									
6									
6									

R5
Were there any foods taken ONLY by the reference child, that the other members of the household did not eat?
(Such as fruits, biscuits, porridge, milk)

					Which ingredients were used?			
	A	Code			**B**	Code		
7								
7								
7								
7								
7								
7								
7								
7								
7								
7								

S-T. CHILD SICKNESS and CHILD CARE

RESPONDENT: MOTHER/MAIN CAREGIVER OF THE REFERENCE CHILD

S	D	S L	VL	HH

Now I am going to ask you about [..*reference child..*]

S. SICKNESS: REFERENCE CHILD

S1 During the past 2 weeks has [..reference child..] suffered from any respiratory infection? (0- No 1- Yes) ☐ .... S11 *If Yes:* How many days did it last? ☐ (88- Don't know)

S2 During the past 2 weeks has [..reference child..] suffered from fevers? .... (0- No 1- Yes) ☐ .... S21 *If Yes:* How many days did it last? ☐ (88- Don't know)

S3 During the past 2 weeks has [..reference child..] suffered from diarrhea? .... (0- No 1- Yes) ☐ .... S31 *If Yes:* How many days did it last? ☐ (88- Don't know)

S4 During the past 2 weeks has [..reference child..] suffered from any other disease? .... (0- No 1- Yes) ☐ .... S41 *If Yes:* What was it? ____________________ (88- Don't know)
S42 How many days did it last? ☐ (88- Don't know)

S5 During the past YEAR, has [..reference child..] suffered from any major illness? .... (0- No 1- Yes) ☐ .... S51 *If Yes:* What was it? ____________________ (88- Don't know)
S52 How many days did it last? ☐ (88- Don't know)

S6 Has [..reference child..] EVER received deworming tablets/treatment? .... (0- No 1- Yes) ☐ .... S61 *If Yes:* When did [..reference child..] last receive deworming?
MONTH ☐ YEAR ☐

T. CHILD CARE: REFERENCE CHILD

T1 Does anyone else besides you look after the child? (0- No 1- Yes) ☐ T11 ***If Yes:*** Who? ☐☐☐

1- Older sister/brother	5- Father
2- House helper/maid	6- School staff
3- Grandmother	7- Other________________
4- Neighbor	8- Other________________

T12 *If yes* , How many days per week do they look after the child?
(Write the number of days per week in the boxes below)

1- Older sister/brother	☐	5- Father	☐
2- House helper/maid	☐	6- School staff	☐
3- Grandmother	☐	7- Other_______________	☐
4- Neighbor	☐	8- Other_______________	☐

T2 Who most often cooks the child's food? ☐

1- Respondent	3- Grandmother	5- Older sister/brother
2- House helper/maid	4- Neighbor	6- Other (specify)____________

T3 How old was [..reference child..] the first time you gave him/her any food or liquid other than breast milk?
(prompt: water, uji, porridge, tea, infant formula, cow's milk)
☐ DAYS *or*
☐ MONTHS

Note: If 3 months or more, confirm to make sure respondent understands that you are asking about ANY food or liquid.

S	D	S L	VL	HH

U. WEIGHT OF THE REFERENCE CHILD

U0 Name ______________________

U1 Sex (0-Male, 1-Female) [ ]

U2 Weight of child [ ][ ] . [ ] kg

U3 Child's clothes [ ]

(0- undressed, 1- Underwear, 2- Light clothes, 3- Light clothes plus sweater)

U4 Date of weighing (DD/MM/YYYY) ____/____/____

If child will not stand on the scale, weigh the mother holding the child, and then the mother alone.

U6 Weight of mother holding child [ ][ ][ ] . [ ] kg

U7 Weight of mother alone [ ][ ][ ] . [ ] kg

U8 Weight of child *(calculate)* [ ][ ][ ] . [ ] kg

U9 Child's clothes [ ]

(0- undressed, 1- Underwear, 2- Light clothes, 3- Light clothes plus sweater)

V. AREAS of TAV PLOTS

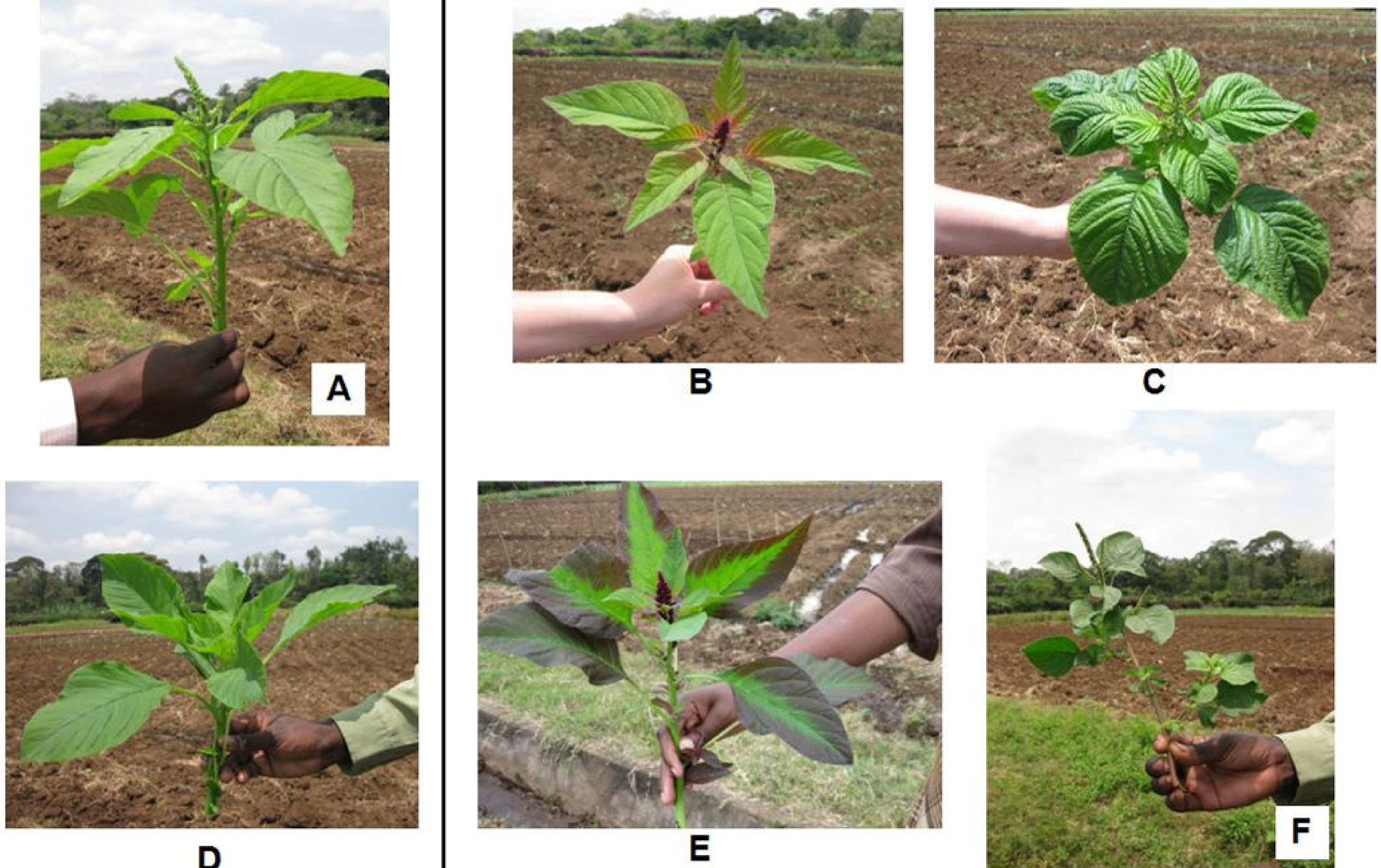
In the table below give the area details of the plots of traditional African vegetables (where applicable).

Pace TAV plots ONLY if farmer was unable to estimate area.

E TAV: 1 Amaranth 2 nightshade 3 spider plant 4 sweetpotato leaf 5 cowpea leaf	F **Pacing for TAV plots** # m **X**	G #m	H **Total m^2**

Kisasa / mpya

Asili / kienyeji



A B C D E F

G- Aina nyingine ya kisasa

H- Aina nyingine ya asili

Kisasa / mpya

A

B

Asili / kienyeji

C

D

E

F- Aina nyingine ya kisasa **G-** Aina nyingine ya asili

A

B

C

D

E

F- Other narrow leaf

G- Other broad leaf

A.7 Community characteristics

Characteristics of Program and Comparison Communities

Project communities	Comparison communities	Location/ access to markets	Population	Average house-hold size	Availability of services (schools, health clinics)	Agronomic characteristics (soil type, temperature, rainfall)	Level of wealth
Tanzania							
Olevolosi*	Kimnyak	Average 5 km to Ngaramtoni market	6285 in Olevolosi 4600 in Kimnyak	6	1 primary school and traditional irrigation systems in Olevolosi 1 primary school, 1 secondary school, 1 dispensary/ MCH clinic in Kimnyak	Arid zone; volcanic soil with high humus content	Kimnyak may be slightly worse off.
Shambarai Burka*	Mbuguni	Good access to Shambarai Sokoni (ward main market) 45km from Tengeru No permanent road, poor access during rainy season	Scattered population: 1501 in Shambarai Burka 1306 in Mbuguni	5	3 pre-primary school, 1 primary school in Shambarai 1 primary school and 1 secondary school in Mbuguni Mbuguni health center accessible to both (closer to Mbuguni)	Lowlands, 500-900m above sea level Sandy loam soil 500mm rain/year	Near a mining town Farms keep indigenous livestock Low income; about 200 Tsh/day ($0.20/day) in Shambarai, $0.50/day in Mbuguni
Manyire	Mlangarini	Tengeru market and Central market in Arusha	2351 in Manyire, 4662 in Mlangarini	5-8	2 primary schools, 1 secondary school, 1 health center and 1 dispensary	75% clay loamy soil, 25% clay soil 200mm rain/year	Low income; about 500 Tsh/day ($0.50/day)

Mzimuni	Marurani	Mzimuni has slightly more access to market than Marurani	1375 in Mzimuni 2300 in Marurani	3	1 primary school, 1 health center (closer to Mzimuni)	Clay sand soil 400-500mm rain/year	Low income; about 300 Tsh/day ($0.30/day) in Mzimuni, $0.40/day in Marurani
Kenya							
Matuguta* Githiha Mungu Irikia Kiongoini Gataka Mahuru Githiga B	Gatitu Kanyore Kiawanjugu Gathangari Gathiong'oi Kabaa	Average 7 km to district market Poor roads and scarce public means of transport	Relatively low population of children < 10 years	7		High altitude arable land with Tea as the major cash crop	
Matimbei* Kamuchege Upper Karinga Gachoire Ngamba Kwa aregi Karugo	Nyanjogu Murera Karatina Mitundu Gathima	Average 15 km to district market Poor roads with no means of transport to the interior	Relatively low population of children < 10 years	7		High altitude arable land with Tea as the major cash crop	
Kiangotho Kaimba	Mukawa King'uru Kang'eng'o Gatwanabu	Average 5 km to the district market and 30 km to the capital market Poor network of all-weather roads Scarce public transport		7		High altitude arable land.	

Karura Ndundu Wangunyu Mukui Nyathuna	Kagongo Munyaka Kirienye Kiberera	Average 5 km to the district market and 30 km to the capital market Fairly good network of all-weather roads but no public means of transport in the interior		7		High altitude arable land and many non-farm enterprises	

*Program communities that already have commercial villages formed from the pilot project phase, 2003-2006

A.8 Report on the pre-testing of the baseline survey questionnaire

The pre-testing was carried out in Arusha, Kiambu and Rachuonyo. The questionnaire was pre-tested with five households in Arusha, one household in Kiambu and two in Rachuonyo. The farmers selected in Arusha and Kiambu were growing Traditional African Vegetable (TAV) and no sweet potatoes while those in Rachuonyo were mainly growing sweetpotatoes. One in Rachuonyo was also growing cassava.

Major observations

- During pretesting, usually the man of the house was responsible for the majority of agriculture (sections A-I), and the woman was responsible for the household food and child care (sections M-U). It was not consistent who was in charge of TAVs (sections K-L). It may be difficult to get both members of the household at once. In several households interviewed, only one partner was available. The enumerators may have to wait for the other partner, or they may have to come back at another time. We should make this clear during training.
- It is important to stress the age range (2-5) because although respondents were asked before the interviews if they had a child age 2-5 and they said "yes", twice when it came to listing household members, actually the child was 6 or 7.
- The questionnaire is quite long, taking 1.5-2 hours. We have looked for ways to reduce certain sections, including having the farmer list crops he/she grows instead of asking a long list; simplifying the question process about inputs used on TAVs; moving some long questions to community-level data

collection; deleting several nutrition knowledge and care practices questions.

- It is very important to explain the purpose of the study transparently. Otherwise respondents may be suspicious (and think they are being taxed), or they may think they will get some financial or food assistance. Both of these erroneous assumptions would lead to the households underreporting their income, assets, land and production. Respondents also must know approximately how long the interview will take and who we are asking to respond, so that they don't get annoyed halfway through the interview (which diminishes rapport as well as data quality). The signed consent forms should help with this.
- Enumerators will be given markers so that if they cannot sign their name, they can mark their thumbprint.
- It seems that the more educated (and wealthy) respondents are, the more likely they are to answer questions and the better quality answers they give. We cannot force people to participate, so the best we can do is to train enumerators to explain well and transparently the purpose of the study and what we are asking of respondents.
- Numbering of the questions – it is not in a good enough state for easy data entry. Needs to be thoroughly reviewed.

Specific observations and changes Table A.1 shows observations from pretesting by section, and suggested responses to the observations. The highlighted observations need special attention for a final decision.

Table A.1: Specific observations and changes

Section	Observation	Response
General	All transactions are in Kshs in Kenya and in Tanzania are Tshs	No need of having currency columns in the tables
A	HHID too complicated	Keep only district, ward, village, and HH number. (Ensure these same categories work in Kenya.) Delete division, location, and sub-location.
A	HH name not there	HH name to be added
A	One cannot complete this page at the farmers' household because it is background information that doesn't depend on questions to the respondents.	Most of this page should to be filled out in the morning in advance of any interviews. Only A9-A15 should be filled out at the household itself.
B	One can mistakenly include persons who have once been members but have since left as members of HH.	Clarify during training that the reference period is the last year, since Oct 2006.
B	If a child is currently in school, respondents always state the current year of school rather than years completed	Order of questions B04-B06 changed to facilitate asking about education and to get consistent information.
B	In Tanzania, the education categories don't follow with responses (Standard level, O-level, A-level)	Education categories redefined to be correct for each country.
B	Economic activities are covered in section J	B08-B09 deleted (later questions replace B08-B09)
C	Getting total cultivated land took a lot of prompting to get a different answer from total owned land.	Adding questions on total amount of land rented from or to others facilitates the thought process to get to total cultivated land.
C	During pre-testing, the question about food security in J was easier to ask and for respondents to understand than the question about food security in C	Food security question in C deleted, because the information is covered in J.
C	No households interviewed had solar power. Why would we need this info even if they did?	Delete

Table A.1 (continued)

C	All households interviewed had a latrine and laughed at the question, because everyone has.	Enumerators consulted and agreed to ask question only if the house may not have a latrine.
C	Number of items currently functioning takes a long time and does not add much value to the asset score.	Collect only total number of items owned, do not ask how many are functioning.
C	Many households are made of stone, mud, AND timber.	Revised housing material categories
C	Respondents are sometimes not in their own homestead compound, making observations of housing material impossible.	Enumerators should insist on interviewing the farmers in their own homes.
C	It is not obvious how many buildings belong to the respondent's household	Added: "How many buildings are in your homestead compound?"
D	Respondents get irritated at the long list of crops, and start to volunteer a list of all the crops they grow. One respondent quit at this point in the interview, saying he didn't like such repetitive questions.	Revised the crop production page to simply list all crops grown, and then train enumerators to prompt the respondent for crops that are important and common (maize) often forgotten (fruits), and the target crops (SP and TAVs).
D	Farmers know the names of some of the crops in their mother tongue	Names of all the crops to be provided in Kikuyu, Luhya, Luo and Arumeru
D	Some farmers cannot tell the name of the TAVs and AIVs grown	Obtain pictures of the various TAVs and AIVs available in these regions
D	Units harvested/sold need work. Farmers used some categories we did not know before.	Add gorogoro (2kg) and 90kgs bag and bundles in the 'weight units'; (other weight categories in the table below).
D	Bananas may come in three categories: sweet green, sweet ripe and cooking bananas	If respondents say they grow bananas, clarify what kind.

Table A.1 (continued)

D	Asking about the three most important staple crops, cash crop and vegetables is confusing because some of staple foods are sold some of vegetables are mainly grown for sale; farmers did not understand the categories.	Ask about the five most important crops grown (in terms of sale), period.
D	Crops like tea are paid according to balance where inputs like fertilizer etc are subtracted by the contracting company	If crop is contracted, note that the income reported is net income
D	All farmers in Arusha could report milk and eggs produced per day, and had to multiply by 7 to get per week	Ask about production of milk and eggs per day
E	Colours of sweetpotato fleshes are confusing to farmers	Clear pictures are required
G	Inputs page is long. Fertilizer, pesticide, irrigation, and labor are recurrent costs, but animals for making ridges, plowing, and plows are not (these are more like assets than inputs).	New version of SP inputs page (G)
I1	Some agricultural groups are existing but dormant	To discuss where to classify these groups
I2	One person cited his church as a non-agricultural group.	Church or mosque or other religious institutions should not be counted as a non-ag group.
I3	Asking to see the budget/record book would take quite a bit of extra time and also diminishes rapport with the respondents (makes them feel that you don't trust them).	Just ask if they have one and trust their answer. (Some households answered yes, others answered no.)
I4	"Do you have a production schedule, to time your production to meet market demand?" doesn't seem to get at the information we're looking for. Everyone says yes.	Delete this question

Table A.1 (continued)

I5	No one had three sources of agricultural prices.	List the one or two most important sources
I6	Farmers did not understand the term "crop quality standards"; unclear what we would really do with information on specific examples of these	Delete this question
J	List of income sources to rank was too long. Also, a statement to sum up income info was needed.	Sources of income list was shortened and moved to last question on the page – useful to sum up income info from the respondent.
K3	It was easier for the respondent to list the months during which he/she grew TAVs than to pick a season from our list.	Change question from choice of seasons to "which months do you grow.."
K	"Seed source" is repeated in the inputs section (L), and doesn't flow well here.	Seed source deleted from table K.
K	TAVs often sold as bundles. Bundle sizes vary by season.	Use a standard size box to estimate bundle size?
K	When asked about the area of TAV plots, some were very small and the farmer said "1 bed" or "3 beds" and couldn't very well estimate the acreage.	It will be necessary to measure the TAV plots, probably with pacing and a tape measure (since GPS is also inaccurate for such small areas).
K	What if the farmer is currently growing a TAV but hasn't harvested any yet?	Ask about TAVs only if they were harvested in the reference period (April-Sept 2007)?
K	Information needed on value addition for TAVs	Added: Do you dry or package TAVs? (tying into bundles doesn't count)
K	Info on production practice of TAVs needed.	Added: How do you grow TAVs; each species by itself, TAVs together, or intercropped with other crops?
L	Inputs section long and cumbersome to ask	Re-designed to ask about key inputs for any of the TAVs previously mentioned.

Table A.1 (continued)

N	General nutrition knowledge questions did not perform well and did not seem to add value	Delete general nutrition knowledge questions; keep only questions on knowledge about vitamin A and iron.
	Source of information on vitamin A and iron only useful in follow-up survey	Delete questions on source of info on vitamin A and iron.
O	Question on when mother learned how to prepare vegetables did not work well	Deleted
O2	Many people did not know of OFSP, so they clearly didn't have any perceptions about health benefits of OFSP.	Ask about sweet potatoes (in general) instead of OFSP?
P	First draft attitude questions didn't work well	Replaced with attitude questions that worked better in pretesting (in Arusha).
Q1	Only porridge is mentioned as meal containing sorghum/millet/maize	Separate ugali and uji into two categories
Q1	Need to separate kales and spinach	
Q1	Dark leafy vegetables category already covered in specific vegetables	Delete dark leafy vegetables category
Q	"How was food obtained" added time to interview	Deleted in 24-hr recall, but kept in 7-day FFQ
Q	Could be useful to compare producer and consumer responses about why they do or don't regularly consume the target crops, and we don't specifically ask this elsewhere in the questionnaire.	Added same question as in consumer questionnaire.
R	It was difficult to estimate the quantities of targeted crops consumed by reference child	Anna is purchasing bowls so that everyone can be asked to estimate quantity using the same standard.

Table A.1 (continued)

R	Respondents always said the child ate more meals than the household, but then reported that the child ate exactly the same food as the household. They needed to be prompted about what the child consumed separately from the rest of the household.	Added: table on items only consumed by the reference child.
T	Questions about cooking the child's food were repetitive	Simplified 3 questions into one – who most often cooks the child's food.
T	Questions about when the child stopped breastfeeding and started eating the normal family meal seemed out of context and difficult for the respondent.	Deleted – to be replaced with recall of days/weeks/months of exclusive breastfeeding
U	It is fine if the child is weighed with light clothes on	Subtract a standard number of grams to account for clothing.
U	Signs of malnutrition are uncommon and may be difficult for enumerators; data may be poor.	Deleted
V	Sketching of the plots should be done before the details of targeted crops are taken although area estimation with GPS can be done after the interview	May not ask enumerators to sketch plots, just count paces.

Measurements In order to calculate the weight of the various units given by the farmers, it was necessary to weigh the various container loads used by the farmers (shown in Figures A.1 and A.2). The results are shown in Table A.2.

Figure A.1: Comparison of "50kg" kiroba/gunia, and large, medium, and small Marlboro bags

Figure A.2: One large Marlboro bag filled with TAVs, within a "50kg" kiroba/gunia sack. The filled bags were weighed.

Table A.2: Measured weights of containers

Type of container	Description	Load item	Load weight
1 bundle	Tengeru market/Central market/Uchumi/Zucchini market	TAV	200-300g
Marlboro bag – small	Tengeru market and on-farm weighing	TAV	2.5kg
Marlboro bag – medium	Tengeru market and on-farm weighing	TAV	4.5kg
Marlboro bag – large	Tengeru market and on-farm weighing	TAV	12kg
Kiroba ("25kg")	On-farm weighing	Nightshade	10kg
Kiroba ("50kg")	On-farm weighing	Nightshade	20kg
Kiroba ("70kg")	Extrapolation	Nightshade	28kg
Kiroba ("100kg")	Extrapolation	Nightshade	40kg
Kiroba ("120kg")	Extrapolation	Nightshade	48kg

A.9 Checklist for checking questionnaires

1. Is there a complete ID number on the top of every page?

2. Is the household name complete and legible?
3. Is there a birthdate for the reference child?
4. If there is a child, is there a weight in section U?
5. Are B08 and B09 filled?
6. When you compare the size of land owned and cultivated (C01 and C04), does it make sense?
7. In D3, is the "is any sold" column filled with 0/1?
8. In D3, are crop codes filled? (particularly sweet/starchy banana)
   - Note: If there is a crop not on the code list, leave the code blank and it will be coded during data entry.
9. For D4 and D5, are both seasons filled?
10. In D4 and D5, if the unit is "4" (bag), is the column for kg/bag filled?
11. Are D6 and D7 filled (milk and eggs)?
12. Does J6 match the information recorded about income sources?
    (a) Sale of food crops from D
    (b) Sale of livestock/livestock products from C and D
    (c) Wages/salaries from J2
    (d) Remittances or pensions from J3 and J4
    (e) Other from "small business" in J2 or other source
13. Are K1-K3 filled?
14. Is K6 filled? (drying TAVs)

15. If TAVs were NOT sold (no numbers in the right side of the table), is K5 filled?
16. Does the information in K4 match the information in D1?
17. Are the written responses in N, O, and P legible?
18. Is Q filled completely?
19. In R, is the "consumed by reference child" column filled with 0/1?
20. Is T filled?
21. If sweet potato, do E06-E09 make sense? Do the totals in E12 = 100%?

When everything is complete, sign the front page at A21.

APPENDIX B

B.1 How program participation was related to changes in TAV production and marketing

There was a significant relationship between program participation and three production and marketing indicators. Active participants significantly increased the number of TAVs they planted and the number of markets they were able to access significantly increased, and there was a significant interaction between program participation group and area of TAVs cultivated (Table B.1).[1]

According to Table B.1, there were several shifts in production and marketing variables that were large in magnitude but did not reach statistical significance. These include: active participants started growing more TAVs than either non-participants or baseline participants. Non-participants decreased the number of markets where they sold TAVs, while market access for participants increased, with the highest increase for active participants. In the participant group, the share of TAV income kept by women appears to have decreased. Active participants are the only group for which change in mean gross and net income exceeded the change in mean implicit value of the crop; participants were able to capture value from their sales in a way that the other groups were not.

[1] Note that in these analyses, district was included as a fixed rather than random effect because it represents proximity to Nairobi, or ease of accessing markets.The dependent variables (harvest, amount sold, gross, net, women's TAV income, and imputed value) were square-root transformed prior to running the models, to satisfy the assumption of normal distribution. Means shown are transformed back to the original; they can be interpreted directly.

Table B.1: Change in production and marketing-related variables from baseline to follow-up, based on program participation*

	n	**Comparison**	**Baseline Only**	**Active participants**
Among all respondents (n=169)		(n = 75)	(n = 31)	(n = 58)
Δ % growing TAVs				
Δ Number of TAVs grown (out of 5)	164	-0.391 [a]	-0.302 [a]	0.839 [b]
Δ % selling any TAVs				
Among households who grew TAVs in either year (n=129)		(n = 31)	(n = 22)	(n = 59)
Δ Area planted in TAVs (acres)*	91	Significant interaction between baseline area*program participation; **see figure 5.4**		
Δ Number of markets where household sold TAVs	125	-0.218 [a] [0.111]	0.172 [ab] [0.156]	0.364 [b] [0.107]
Households who grew TAVs in season in either year and had harvest data (n=79)		(n=22)	(n=8)	(n=46)
Δ Harvest (kg/6-mo season) (geometric mean)	76	5.64 [159.95]	844.37 [231.83]	295.43 [68.16]
Δ Amount sold (kg per 6-month season)	77	50.15 [133.91]	257.41 [171.66]	104.12 [52.07]
Δ Imputed income (value of TAVs grown)	76	$11.81 [42.64]	$190.80 [64.61]	$26.44 [18.71]
Households who sold TAVs in either year		(n=13)	(n=7)	(n=45)
Δ Gross TAV income per season (USD)	65	-$3.01 [60.39]	$169.70 [58.08]	$35.03 [16.96]
Δ Net TAV income per season (subtracting input costs)	65	-$1.72 [52.03]	$156.38 [55.18]	$32.84 [14.15]
Households who sold TAVs in both years		(n=6)	(n=6)	(n=44)
Δ Percent of (gross) TAV income that women keep	56	28.86 [12.79]	-21.27 [13.88]	-9.78 [6.94]
Δ Women's gross TAV income per season ("money in the pocket")	57	$16.44 [26.23]	$8.36 [35.00]	$10.68 [8.37]

Notes: Means were adjusted for district, change in wealth, baseline wealth, age of

Table B.1 (continued)

household head, baseline value of the variable, and the interaction between baseline value and participation. Models also controlled for village as a random effect. Equality of proportions was tested using Pearson chi-sq test statistic. **Means with different superscripts are significantly different using Tukey's HSD criterion. Means with no superscript are not significantly different.**

The lack of significance may be explained by the fact that some sample sizes were very small for these production and marketing models. That is because models on production and number of markets were only run on those who were producing TAVs at the time of the survey, and were further reduced by some implausible estimates of harvest amount. Models on sales were run on only those who sold any TAVs, which is fewer than those who grew. When compared to the number of households that grew TAVs in the year - 129 (76%) and 139 (82%) of households grew TAVs in one or both survey years in Kiambu and Arusha, respectively - the sample for which area and harvest are estimated is smaller. That is because for some TAV-growing households, TAVs were grown in the past year but not the season immediately preceding the survey, and for some households, they had planted TAVs for the first time that season, but the TAVs had not yet been harvested, so no harvest estimates were possible. The small sample sizes are explained by the shorter recall period for harvest data than for asking whether or not TAVs were grown:

- Growing TAVs: recall was last 12 months
- Area: recall was last 6 months
- Harvest: recall was last 6 months. In some cases, TAVs were in the field (so area was recorded) but not yet mature, so harvest amount was not applicable.

Furthermore, harvest data was quite complex to estimate, and some households estimated implausibly high data. Data were considered implausible if the mean TAV yield obtained was more than four times higher than the mean published yields for the five TAVs in the survey. Yield (kg/hectare/season) and harvest (kg/season) were difficult to estimate because:

- Farmers could plant multiple times per season
- TAVs can be harvested multiple times per planting
- Usually harvest is piecemeal, so the farmer must estimate on average how much was obtained for each small harvest. Sometimes that looked like 3 kirobas (12-kg sack) twice per month, and sometimes it looked like 3 bundles 30 times per month.

At baseline in Kiambu, out of all those households who grew TAVs, 31% had planted them in the previous season or this season's crop had not yet been harvested, so harvest data could not be obtained. At follow-up, 22% had planted in a different season or had not yet harvested. Out of all those households who grew TAVs, 4% of households were eliminated for having implausibly high harvest estimates (above four times the mean typical yields for the TAVs grown). Typical yield values were obtained from AVRDC (unpublished data), and the average for all five TAVs was 10 tons per acre (25 tons/ha). In sum, when taking the difference of harvest observations at follow-up and baseline, 50% of all those households who grew TAVs at any time, either year, had two years of valid harvest data.

APPENDIX C

C.1 Comparison of households included in the analysis with households lost to follow-up

Households lost to follow-up (n=20) were equivalent to those who were surveyed both years (n=338), except that those lost to follow-up had significantly less land in both study sites. (See Table C.1.)

Of the households lost, 10 moved away to cities, three were traveling during the time of the survey, six refused all or large sections of the questionnaire, and in one household a spouse had died and the household no longer farmed.

In all cases but the six who refused, land size could be related to the lost to follow-up households' relatively weaker ties to their residence. Those who had less land to begin with might be more likely to travel to other places for work or to stay with family, to stop farming, and to move to cities. Alternatively, households who had a plan to stop farming and move away may have been in the process of selling off pieces of land, so that their average land size was smaller than among farmers who had no intention of leaving.

In conclusion, it does not appear that those who remained in the survey are a biased sample of farmers in the study sites. Based on the single characteristic that differed between those who remained and those lost to follow-up (land size), it appears that the difference merely reflected the propensity to stop farming and leave town, which most of the households lost to follow-up did.

Table C.1: Comparison of households included in the analysis with households lost to follow-up

	Final sample	Lost to follow-up
KIAMBU	(n = 169)	(n = 12)
Years of school (head)	8.8	8.9
Years of school (mother) †	8.6	7.8
% female-headed households	13.0	25.0
Wealth (asset ownership) (geometric mean)	$1113	$770
Number of off-farm income sources	2.0	1.6
Land size	1.62*	0.88*
Age of household head	48.1	43.1
Household size	4.91	4.25
Number of children under age 5	0.89	0.67
ARUSHA	(n = 169)	(n = 8)
Years of school (head)	6.5	5.8
Years of school (mother) †	6.6	6.1
% female-headed households	15.4	25.0
Wealth (asset ownership) (geometric mean)	$727	$241
Number of off-farm income sources	1.1	1.5
Land size	3.27*	2.00*
Age of household head	40.9	33.9
Household size	6.51	6.25
Number of children under age 5	1.38	1.25

Notes: Equality of proportions was tested using Pearson chi-sq test statistic. Equality of means was tested using a t-test (2-tailed), equal variances not assumed. † The household "mother" (the person who cares for the reference child age 2-5 or if no reference child, the person who prepares the majority of the household food) is sometimes the same as the head of the household, but usually not. *Differences between groups are significant at the $p<0.05$ level.

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